RESPONSE TO UNESCO RECONSTRUCTION APPEAL

from

INDEPENDENT AID

NEW YORK CITY

through

*The Hive and 'he Honey Bee*

# The Hive and the Honey Bee

*A new book on beekeeping to succeed the book "Langstroth on the Hive and the Honeybee"*

EDITED BY ROY A. GROUT

With the Collaboration of
A Staff of Specialists

*REVISED EDITION*

DADANT & SONS · HAMILTON, ILLINOIS

*Publishers of the American Bee Journal*

1949

Extensively Revised 1949



PRINTED IN THE U. S. A. BY R. R. DONNELLEY & SONS COMPANY
CHICAGO, AND CRAWFORDSVILLE, INDIANA

## DEDICATION

*To the former authors of "The Hive and the Honeybee,"*
*Lorenzo Lorraine Langstroth,*
*Charles Dadant, and Camille Pierre Dadant,*
*this book*
*affectionately is dedicated by the co-authors.*

"Place yourself before a hive, and see the indefatigable energy of these industrious veterans, toiling along with their heavy burdens, side by side with their more youthful compeers, and then judge if, while qualified for useful labor, you ought ever to surrender yourself to slothful indulgence."

*L. L. Langstroth*

# *FOREWORD*

"LANGSTROTH on the Hive and the Honey-Bee, a Bee Keeper's Manual" was the title of the original book by Rev. L. L. Langstroth in 1853. Langstroth was the originator of the movable-frame hive and his book presented a system of management which allowed the beekeeper full control of his bees. Langstroth probably little realized what a great expansion in beekeeping would come from the use of his hive and his system, or that beekeeping would one day be a specialized business.

After 1859, because of ill health, Langstroth could not make a revision of his book but the demand for it still continued. In October, 1885, he visited Charles Dadant at Hamilton, Illinois, and arranged for him to bring the book up to date. It was then largely rewritten to be published again, in 1888, for an equally enthusiastic public. Soon it was translated into the French, Russian, Italian, Spanish, and Polish languages.

Charles Dadant died in 1902, and later revisions were the work of his son, C. P. Dadant, who died in 1938. Twenty-three editions of the original book were issued during the life of these three men.

More than twenty years had passed since the last important revision, and so many changes had occurred in beekeeping that a new book became necessary. Because it was entirely written by a group of authors, each recognized as a specialist in his particular field, it could no longer be called a revision of Langstroth's original work. Instead it became the combined contribution of several men, each writing the part with which he was most familiar.

Although less than three years have passed since this new book appeared, a further revision is here made with the addition of three new names to the group of authors. Necessary changes may be found throughout the volume and several chapters have been entirely rewritten. Many new illustrations are used and the chapters rearranged for greater convenience in classroom use.

# *ACKNOWLEDGMENT*

DADANT & SONS, publishers of the *American Bee Journal*, especially desire to express their thanks and appreciation to the following co-authors of this first revision of the book and for illustrations furnished by them. While the name of the author appears at the beginning of each chapter, acknowledgment for their contribution to this volume is given here to:

A. Z. Abushâdy
Gladstone H. Cale
Henry C. Dadant
Maurice G. Dadant
John E. Eckert
Clayton L. Farrar
Roy A. Grout
James I. Hambleton
Carl E. Killion
Newman I. Lyle
Vern G. Milum
O. W. Park
Frank C. Pellett
Robert E. Snodgrass
Arnold P. Sturtevant
R. B. Willson

Appreciation and acknowledgment likewise is given to the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, for permission to publish the manuscripts of C. L. Farrar, James I. Hambleton, R. E. Snodgrass, and A. P. Sturtevant; to the University of Illinois for permission to publish the manuscript of V. G. Milum; to Iowa State College and the Iowa Agricultural Experiment Station for permission to publish the two manuscripts of O. W. Park; and to the University of California for permission to publish the manuscript of J. E. Eckert. The more than one hundred original drawings of the anatomy of the honey bee by Robert E. Snodgrass were loaned by the Bureau of Entomology and Plant Quarantine and are not included in the copyright of this book.

Various portions of *Langstroth on the Hive and the Honeybee*, 23d edition, 1927, revised by C. P. Dadant, as well as various portions of previous editions of that book, have been freely incorporated with or without individual citation. For the use of this material, due acknowledgment is gladly given by the authors.

The editor desires to express his appreciation to Maurice G. Dadant and Gladstone H. Cale, of the *American Bee Journal* staff, and to Minnie S. King, Frances Rowe, and Adelaide D. Fraser for their critical assistance in the preparation of the manuscript of this book; and to Gladstone H. Cale, Jr. for assistance in the preparation of illustrations.

# TABLE OF CONTENTS

*The Hive and the Honey Bee*

# I. *The Beekeeping Industry*

BY ROY A. GROUT*

BEEKEEPING had its beginning in antiquity before the earliest written history of mankind. Fossil remains indicate that the honey bee appeared on earth before man. And man learned that honey was a delicious, sweet food long before he devised means of establishing bees in convenient places to provide a more accessible supply of honey.

In ancient times beekeeping was a serious matter requiring much skill and care. The hives and equipment we now use were unknown. Receptacles in which bees lived often were mere cavities made from earth. It was not possible to examine the combs. In spite of this, the ancients, from Aristotle to Palladius, established a remarkable wealth of information about bees and beekeeping practice. H. Malcolm Fraser[1] states, "Then, as now, beekeeping was an occupation which knows no distinction of rank or wealth: Pliny's consul, Virgil's small-holder and Varro's soldiers, can all be paralleled today, and rich and poor will meet as beekeepers on equal terms, because success in the art depends on skill, not capital."

Honey was man's chief sweet and usually was obtained by cutting out a part of the combs. It was used as food in the home, and physicians generally were aware of its health properties and used it in prescriptions. Priests required honey for religious purposes, and taxes often were levied in honey and beeswax. Coffins were made tight with beeswax and it was used in mummification of the dead. It was also used to furnish light, for writing tablets, by physicians in medicines, and by artists for statuettes and for painting. Beeswax was an important article of commerce.

Migratory beekeeping, a well-known practice today, probably originated in ancient Egypt. The hives were placed on rafts from which the bees flew to gather honey. As the season advanced, the rafts were moved down the Nile River to a point where there were new flowers. Thus, these apiaries were floated down the Nile to Cairo where the honey was marketed.

We can follow the history of beekeeping for two thousand years with but little change in management methods and with little improvement

---

*The author has freely incorporated herewith, either with or without change and without individual citation, various portions of Chapter I, by Frank C. Pellett, in the first edition of this book, and due acknowledgment is gladly given.

[1]Fraser, H. Malcolm. 1931. *Beekeeping in Antiquity.* London. University of London Press, Ltd. p. 148.

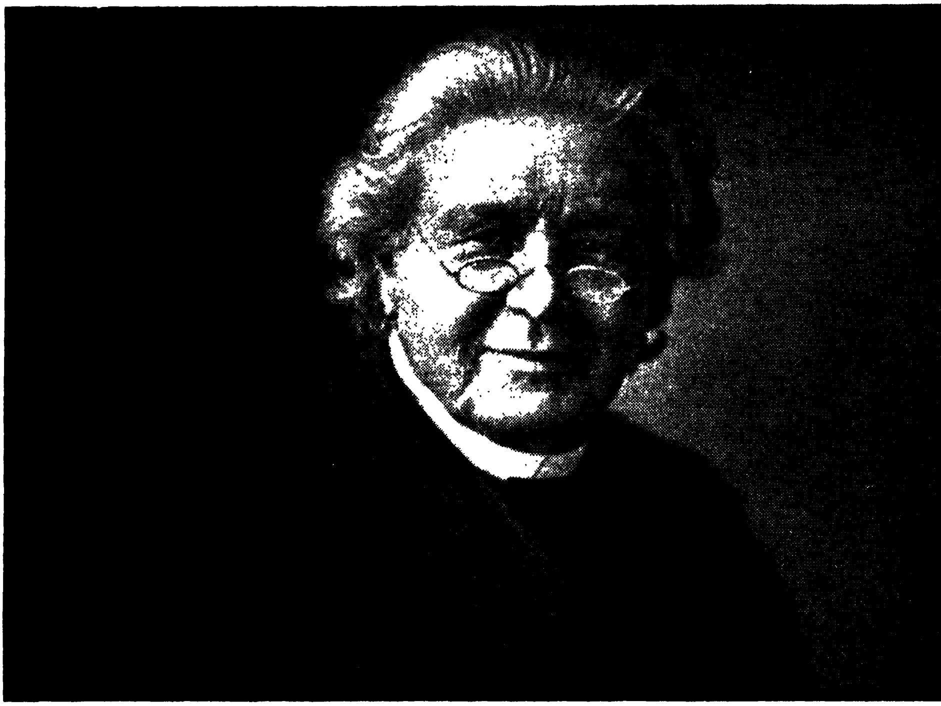


FIGURE 1. Lorenzo Lorraine Langstroth, the father of American beekeeping.

in either bees or equipment. Men were satisfied to hive the swarms and take the meager amounts of honey by killing the bees and melting or crushing the combs, or by cutting out a portion of the combs while there was yet time for others to be rebuilt and stores replenished before the end of the season.

## Early American Beekeeping

When the colonists came to America they brought with them the honey bee, and the Indians called it the "white man's fly." These bees were kept in nondescript hives, consisting of boxes, kegs, and bee gums made from hollow logs, and box hives which were manufactured as early as 1645. Even two hundred years later, the most useful hive was a box for a brood chamber, with a hole in the top and a cap, or surplus chamber, above for the storage of surplus honey.

When Langstroth (Fig. 1) discovered the bee space in 1851, he revolutionized beekeeping and made possible its present extent. By observing that bees left a space or passageway of approximately five-sixteenths of an inch between their combs, he discovered one of the most important habits of the bee. Taking advantage of it, Langstroth developed his hive which was open at the top and contained hanging frames, each

surrounded on all sides by a bee space. Now it was possible to remove the combs and to establish management for honey production.

Two other improvements also appeared in the invention of bee comb foundation and the honey extractor. Bees previously had built combs in the hives with little to guide them. In 1842, Gottlieb Kretchmer, a German, made comb foundation by passing tracing cloth dipped in beeswax through metal rollers and, in 1857, Johannes Mehring, also of Germany, invented a wooden press which successfully made comb foundation. This invention was soon introduced into this country and devices for making it developed rapidly. With later improvements in the manufacture of comb foundation, combs constructed on it were more perfect than those constructed by bees at will. The honey extractor, the principle of which is accredited to Major Franz von Hruschka, an Austrian, in 1865, made it possible to remove honey readily from the comb by machinery for the first time.

During this time, men had little interest outside their home surroundings and beekeeping offered an enticing occupation. With the establishment of the *American Bee Journal,* the first periodical about bees in English, beekeepers found a common means of contact. Interest developed rapidly and new publications arose so frequently that it is now difficult to compile a list of them. More than one hundred magazines were started in half as many years.. Some soon disappeared while a few continued publication.

With the availability of information came an epidemic of inventions and changes in hives and equipment. The greater part of the material had little merit. With hundreds of new hives, little was added to Langstroth's original one which still is used substantially as he made it.

With large quantities of honey available in liquid form, it became common practice to adulterate it with an addition of sirup. In 1878, Charles Dadant[2] started a movement opposing the adulteration of honey and for the establishment of a federal law against such practices. The beekeeping industry joined him enthusiastically. Years later, after powerful interests were brought to bear, the Pure Food Law was passed by Congress, in 1906, bringing protection to the food supply of the nation. This paved the way for an increasing supply of honey free from adulteration, and honey rapidly became accepted by the public as a pure food.

The period from 1875 to the first World War, is often called the "golden age of beekeeping." Bees were common on farms as a part of home support, and there was keen interest in their behavior. The journals were filled with argument and comment about the way bees do things. Conventions were great social events attracting attendance from long distances, and discussion centered on the habits of bees rather than the sale of their products, the monetary return from beekeeping being

[2]Pellett, Frank C. 1938. *History of American Beekeeping*. Ames, Iowa. Collegiate Press, Inc. pp. 206–213.

secondary. More progress was made in understanding the fundamentals of beekeeping than in any other period, and many books were published to guide the beekeeper in his favorite occupation.

The total number of beekeepers was probably more than half a million, but the proportion of commercial honey producers tended to increase considerably while the number of small producers decreased, many being put out of business by bee diseases. Many of those keeping bees as a diversion lost their interest when other means of entertainment, such as the automobile, the radio, and the movie, made their appearance. Many did not care to meet the competition which arose for honey in the markets when corn sirups became available and the cane- and beet-sugar industries expanded. This trend continued until those beekeepers who were interested mainly in returns which they received from their beekeeping efforts were in the majority.

## Effects of the World Wars

The first World War caused a serious shortage of sugar, and honey brought a high price. Consequently, the industry made great expansion and the production of honey offered full-time occupation for many people. The great extension of the honey-producing area, provided by the general use of sweet clover, gave further expansion until beekeepers operated from a hundred to five hundred colonies, frequently a thousand to five thousand or more. Many an individual produced more honey than dozens had produced previously.

Following the war, prices fell to a low figure and the demand for honey became sluggish. Any food-producing industry in this highly competitive time had to have either a large advertising fund or a highly enthusiastic amateur element. Lacking both, the honey industry found that demand and price had sagged further than supply, and in the depression years of the 1930's the price of extracted honey dropped to 4 cents a pound.

Self-preservation, the first law of all nature, became the operative force which began a change in the marketing of the products of the hive. It was at this time that the co-operative as a means of marketing honey became established. Also, co-operative educational effort was begun by the American Honey Institute which informed many people for the first time that honey was a delicious, healthful food and acquainted them with efficient ways of using it.

With the advent of the second World War the beekeeping industry again passed through a period of great change. Beeswax was in great demand. Honey was sought eagerly for use in place of sugar which experienced a prolonged world shortage. It became necessary to place a ceiling on the selling price of both honey and beeswax for the protection of the industry as well as the consumer.

Many changes also took place in bee pasture. In many areas honey plants were replaced by cash food crops, compelling a reduction in the number of bees. The widespread use of insecticides poisonous to honey bees took a further toll. And the necessity for the pollination of fruits, vegetables, and field crops required the presence of honey bees more than ever because of the concentration of acreage devoted to these crops.

Since the end of the war, great emphasis has been placed both on the need for bees in the pollination of more than fifty food crops[3] and the restoration of rotation practices which include legumes in the interest of soil conservation. This has tended to bring about many small apiaries, in areas where bees previously were disregarded, for the purpose of insuring proper pollination and greater yields of food and seed crops. And increased recognition is being given to the value of honey bees from a pollination standpoint by the insecticide people in their consideration of recommended measures in insect control.

## The Extent of Beekeeping

Honey bees are found in every state in the United States. It is estimated that there are about 600,000 people who keep bees, from those with one colony to those with several thousand. Honey bees are kept both as a vocation and an avocation, some people depending on their bees for all or a part of their living (Fig. 2), while others keep bees solely for the pleasure derived from working them or for the services the bees render in pollination.

The extent of beekeeping is influenced by soil and climatic factors which, in turn, affect the amount and kind of floral sources that furnish nectar and pollen for the bees. These sources also determine the number of colonies which can be kept profitably in one place and the beekeeping practices used by the beekeeper. The type of agriculture which prevails also has its part in shaping the kind and extent of beekeeping. Inasmuch as the beekeeper does not have complete control over these factors, success is a measure of his skill and ingenuity in managing the bees in such a way as to take full advantage of whatever situation may arise.

According to the United States Department of Agriculture, Bureau of Agricultural Economics, in 1947, 5,910,000 colonies of bees produced 228,162,000 pounds of honey and 4,492,000 pounds of beeswax. At the price levels which then prevailed, the honey crop was valued at $59,-263,000 and the beeswax crop at $1,966,000. These figures have greater significance if we consider the fact that the services that the bees render agriculture in the cross-pollination of fruits, vegetables, legumes and other seed crops are worth many times the returns which the beekeepers

[3] 1942. The dependence of agriculture on the beekeeping industry. *U.S.D.A. Circ.* E-584.

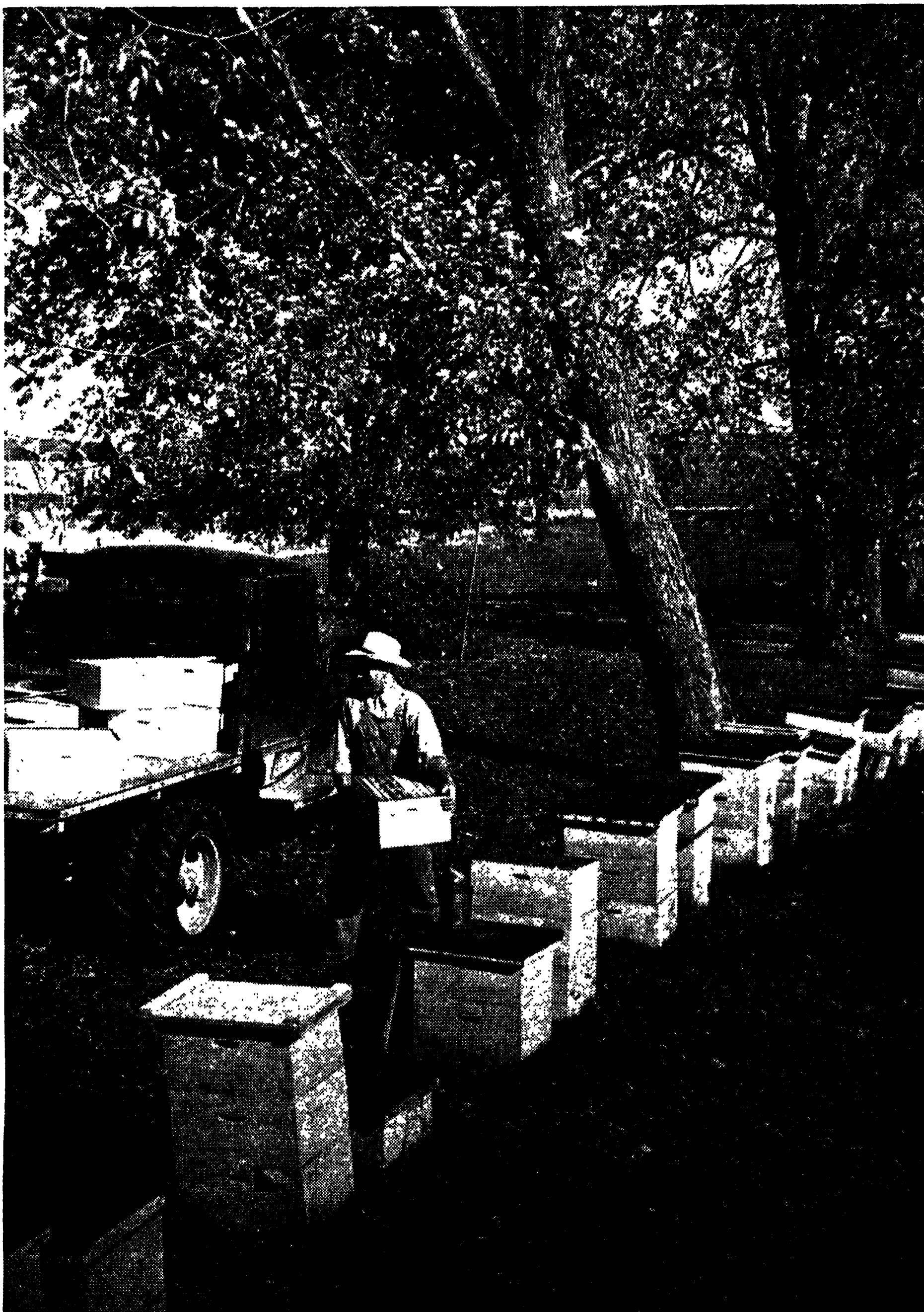


FIGURE 2. The back row of colonies in a modern, well-managed apiary, a part of an apiary system which provides a full-time occupation for its owner. (*Photo by J. C. Allen and Son*)

receive. Beekeeping, therefore, is not just a branch of agriculture; it is often the very basis of it.

## Effect of Flora on Beekeeping

It is extremely difficult to designate definite regions or to set up boundaries in relation to flora and beekeeping practice. Voorhies, Todd, and Galbraith[4] divided the United States into eight regions to discuss the geographic distribution of beekeeping: the white clover belt, the southern district, the Plains area, the Intermountain district, Texas, Arizona, California, and the Pacific Northwest. Phillips[5] divided the country into five regions: the white clover region of the Northeast, the southeastern regions west to Texas, the alfalfa area of the West, the sage area of southern California, and the semiarid region of Texas and adjoining states.

Although many wild plants contribute to the support of the colony, beekeeping today depends chiefly upon cultivated plants and pasture crops for a source of surplus honey. Thus we find large apiaries where legumes are the main source of surplus honey in the Midwest, in the irrigated valleys of the Intermountain States and the West, and in California. The flora of the Northeast and Eastern States is more inducive to small apiaries, although there are many areas, such as the buckwheat area of New York, where large beekeeping operations are possible. In the South, climatic conditions generally are more adapted to specialization in queen rearing and the production of package bees, although many areas produce substantial crops of honey. For additional information on the effects of flora on beekeeping, see Chapter XVIII, "Sources of Nectar and Pollen."

## Who Should Keep Bees

To be successful, the beekeeper must be somewhat of a naturalist. He must have a thorough and practical understanding of bee behavior in order to know how to do the right thing for his bees at the right time. He sincerely needs knowledge concerning nectar and pollen plants, and the soil and climatic factors that influence nectar secretion. Many successful commercial beekeepers are mechanically inclined, if not ingenious, devising efficient and economical ways of operating their beekeeping outfits. All should be students of the literature concerning bees, beekeeping methods, honey plants, and agriculture. Because of changing conditions—the variation in seasons, changes in agricultural practices, the introduction of new methods of beekeeping—his ingenuity often will be taxed to

---

[4]Voorhies, Edwin C., Frank E. Todd, and J. K. Galbraith. 1933. Economic aspects of the beekeeping industry. *Calif. Agr. Exp. Sta. Bull.* 555. p. 9.

[5]Phillips, E. F. 1928. *Beekeeping*. Revised ed. New York, N. Y. Macmillan Co. p. 221.

understand what to do. Many beekeepers are always trying new and different methods, adding much to the interest of their vocation or avocation.

Altogether, beekeeping is an interesting, if not unique, occupation attracting people of all classes—professional men, business men, craftsmen, almost every type of individual. Many women are successful beekeepers, and many of the practices of beekeeping, such as preparing honey for the market and the rearing of queen bees, are more suited to their capabilities than to those of men.

Those who are hypersensitive to bee stings, or exceptionally nervous, will find it difficult to keep bees. The majority of people, after having become accustomed to bee stings and eventually immune to their effect, will pay little attention to them. At times, beekeeping is hard work, and those who are not physically strong or who are incapacitated will find it necessary to have help. Nevertheless, many who are blind or physically handicapped find pleasure in keeping bees. For additional information on bee stings and who should keep bees, see Chapter VII, "First Considerations in Keeping Bees."

## Types of Honey Production

There are three types of honey production: extracted honey, section comb honey, and bulk comb honey production.

The management of the colonies is the same for all three types of honey production with the exception of the summer period when the crop is harvested. This management is discussed in detail in the following chapters in this book: Chapter VIII, "The Apiary," Chapter IX, "Common Practices in Management," Chapter X, "Management for Extracted Honey Production," and Chapter XIV, "The Overwintering of Productive Colonies."

The equipment needed for the honey-bee colony and its management is the same for all three types of honey production with the exception of the summer period when the crop is harvested. The beehive consists of a bottom board, preferably set on a hive stand to raise the colony off the damp ground; one or more hive bodies which, together with the combs they contain, form the brood nest where the young bees are reared and where honey and pollen for food are stored; and an inner cover and an outer cover. The apiary equipment generally includes the bee smoker, the bee veil, bee gloves, and a hive tool. The beehive and the apiary equipment are described in detail in Chapter VI, "Beekeeping Equipment."

The supers, where the honey crop is stored, and the other equipment employed during the summer season when the crop is harvested are different for each of the three types of honey production. For the production of extracted honey, two or more supers are required for storage of the

honey crop, plus equipment for removing and extracting the honey (see Chapter X, "Management for Extracted Honey Production," and Chapter XI, "Extracting the Honey Crop"). Special supers containing sections furnished with special comb foundation are required for the production of comb honey (see Chapter XII, "The Production of Comb Honey"). Regular supers containing frames equipped with special comb foundation are required for the production of bulk comb honey (see Chapter XIII, "The Production of Bulk Comb Honey").

Extracted honey, sometimes called strained honey, goes to market as liquid honey packed in glass or tin containers, and as granulated honey which "has gone to sugar" in a natural way or which has been processed in such a way as to result in finely granulated honey, called creamed honey. Section comb honey goes to market in the wood section in which it is produced, but usually wrapped attractively in a cellophane wrapper. Bulk comb honey is marketed as cut comb honey wrapped in cellophane similar to section comb honey, or as chunk honey surrounded by liquid honey in glass or tin containers. For additional information concerning market forms of honey, see Chapter XV, "Honey," and Chapter XVI, "Marketing the Honey Crop."

Most beekeepers produce extracted honey because it does not require the specialized effort necessary for the production of the other two types, and a greater quantity of honey can be obtained. Considering the country as a whole, extracted or liquid honey is desired by the greatest number of consumers. Some beekeepers choose to produce section comb honey which always finds a ready market, while others find that bulk comb honey is best suited to their local markets. It is probable, however, that less than 20 per cent of our honey production is in the form of section comb honey and bulk comb honey.

## Specialized Beekeeping Practice

Many beekeepers rear their own queens in late spring and summer, but queen rearing has become a specialized beekeeping practice in the South and in California where the season is long, and nectar and pollen are available early in the year. While some specialize solely in the rearing of queens, most produce package bees for shipment to beekeepers and rear the queens which accompany them, as well as produce additional queens for their customers. For additional information, see Chapter XXI, "The Production of Queens and Package Bees."

The furnishing of bees for pollination purposes is another specialized practice of beekeeping which is increasing in scope. In a few instances, bees are kept entirely for pollination purposes, but in most cases the furnishing of bees for pollination of crops is done in conjunction with the production of honey. Usually, bees are moved by the beekeeper to the orchard, greenhouse, or farm where cross-pollination is required, and re-

moved to locations more suited to the production of honey when pollination has been accomplished. Inasmuch as the beekeeper may experience a loss of honey due to moving his bees and because his colonies sometimes suffer a reduction in colony strength due to insecticide poisoning, he usually is paid for the pollination service (see Chapter XVII, "The Honey Bee as a Pollinating Agent").

## Returns from Beekeeping

While honey crops amounting to from one hundred to two hundred pounds from a single colony in a year are not uncommon, it is wise to point out that the average per-colony yield, as reported by the U. S. D. A., Bureau of Agricultural Economics, for the entire country was 38.6 pounds for 1947. Beekeeping usually is not a path to quick riches, but most people who become fascinated with beekeeping find in it a sound financial return plus personal pleasure and satisfaction.

Over a period of 62 years, which excludes the war years, the average price of honey has been slightly more than 7 cents per pound on the wholesale market. If we include the high prices during the two World Wars, the average price over a period of 72 years has been 8.7 cents for honey on the wholesale market. The cost of operating a colony of bees has varied from around $2 to as high as $7 or $8 each year, depending on the costs of labor and materials, with an average operating cost of approximately $5. Beekeepers have enjoyed a degree of prosperity equal to that of any other agricultural group. For additional information on the cost of honey production, see Chapter VII, "First Considerations in Keeping Bees."

Looking ahead, it can reasonably be expected that the interest in bees as a part of the agricultural program through pollination services will be greater, and that the number of those who keep bees on a small scale will increase considerably. Improved organization of the industry through the American Beekeeping Federation and increased educational efforts and advertising of honey by the American Honey Institute pave the way for a much brighter future. The advent of disease-resistant bees, new methods of disease control, improvements in bee breeding through controlled mating, and recognition of the importance of bees to agriculture by the insecticide industry and farmers bring the beekeeping industry to the dawn of a great new day.

# II. *Races of Bees*

BY A. Z. ABUSHÂDY*

ALTHOUGH American honey bees are acknowledged varieties of European bees belonging to the species, *Apis mellifera* L., they are from a practical point of view distinctly ahead of their European ancestors. From these early ancestors, the first honey bees of America were evidently derived by some of the pioneers who did not forget their various pets, including honey bees, when they immigrated to this country. Research confirms that the American Indians had no knowledge of the honey bee prior to this time, hence their calling it the "white man's fly."

Considering that shipment of honey bees properly packed in their primitive hives was practiced centuries ago by nations of antiquity, particularly by the ancient Egyptians, the continuation of such a practice by immigrants to America, using the traditional skeps with a reasonable degree of success, is understandable. Notwithstanding the recognized craftsmanship of beekeeping in Europe, the people also were fond of their winged friends. Thus, in all likelihood the Dutch or Scotch immigrants, who were accustomed to migratory beekeeping, were pioneers in this field, bringing with them the heather brown honey bees of Europe. This took place long before the introduction into America of yellow and grey bees, mainly from Italy, and from Carniola and Caucasia, respectively.

The valuation of time and productivity, to an extent that has become an American characteristic, has led to the elimination, through ceaseless selection, of all strains of honey bees that were time consuming in manipulation due to nervousness or bad temper or because they were not relatively productive. As a consequence, the prevailing races and strains of American bees, a number of which are noted for hardiness, increased productivity, and comparative immunity to disease, are altogether worthy of the industrial and scientific standards of the country.

As a young nation, Americans were at one time looking to Europe with a feeling of inferiority which, through lack of scrutiny and discrimination,

*Ahmed Zaky Abushâdy, M. D. Poet, beemaster, humanist. Founder of The Apis Club, an international federation of beekeepers, in 1919, and *The Bee World*, a monthly bee journal of international scope published in England. Founder of the Bee Kingdom League and its publication, *The Bee Kingdom*, in Egypt. An international leader in the standardization of beekeeping equipment and the improvement of races of bees. Formerly vice-dean of the faculty of medicine and professor emeritus of bacteriology, Farouk University, Alexandria, Egypt. Past delegate and adviser at the United Nations Organization, and now permanently residing in the U.S.A.

led to the introduction of bee diseases from Europe. The reversal of this policy is now timely; importations are now limited to such strains as are required for experimental breeding and investigation by universities, research institutions, and government laboratories, which employ artificial insemination in their selective breeding. As one who has practiced beekeeping under various conditions in three continents for many years, the writer has no hesitation in testifying to the all-round excellence of American bees and in upholding the insular policy of the Department of Agriculture.

Where European bees are not available, beekeepers have no choice but to make use of, or to take advantage of, these native bees, wild or domesticated. But progressive beekeeping in Eastern, as well as in African, countries is giving full attention to Western or rather to "standard bees," which alone merit consideration in a practical book on bee culture, leaving the academic description of others to works of reference.

Although various species of bees are known in the Far East, chief amongst which are the honey bees of India, China, and Japan, they are not of distinct economic value. These include the giant bee of India, *Apis dorsata;* a medium-sized bee, *A. indica,* a variety of *A. mellifera* but smaller than standard bees; and the tiny bee of India, *A. florea. A. dorsata* and *A. florea* build only a single comb while *A. indica* constructs several.

## Standard Bees

By "standard bees" is meant those races of bees which maintain their fundamental characteristics in their adaptability to various environments. In addition, experience has shown these bees to be more resistant to European foulbrood than other races. In broader terms they are "global" honey bees.

The three races of *Apis mellifera* L. that are more deserving than others of this classification are: Carniolans, Caucasians, and Italians. The first two comprise "grey" blood, while the last represents "yellow" blood.

Inasmuch as it is not practically possible within a lifetime (except through an intensive policy under governmental supervision applied to a comparatively small territory) to replace the entire native bee population of a country by standard bees, the best practical policy would be to effect crossings between standard bees and native ones. To achieve the best results whenever such crossings are possible, recognition should be made of the fact that wherever the native bee is of the yellow type the introduction of grey blood is advantageous, and vice versa. For example, the honey bees of Egypt belong to the yellow class; therefore, it is more advantageous for both discrimination and for breeding considerations to utilize grey blood (Carniolans or Caucasians) rather than yellow (Italians) in crossing them. Otherwise, the resultant cross is likely to result in nervous and vicious bees that resist queen introduction and are time consuming in manipulation

of colonies. On the other hand, where the native bee is brown or dark-colored, as in Britain and in many parts of the continent of Europe, yellow blood (Italians) is more desirable for crossing because of similar reasons.

The progress of modern beekeeping is as much dependent on the improvement of bees as on the standardization of hives and equipment. It behooves us to concentrate on the propagation of standard bees and on the breeding of their *first crosses* with native bees, whenever possible.

### Carniolan Bees

Natives of Carniola, now part of Jugoslavia, these bees show their best qualities in Alpine regions. This is the reason for the special demand for Alpine Carniolans which are regarded among the finest grey bees in existence, and by many as the premier race of hive bees. The abdominal segments are dark grey with bands of comparatively whitish colored hairs.

They are the largest of hive bees and are extremely gentle, quiet on their combs, good breeders, almost nonpropolizers, hard workers, long lived, economic consumers of stores, and good winterers. They are honest workers, unlike Italians which are prone to robbing, and are well disposed toward queen introduction. They build regular combs with white cappings that are well suited for comb honey production.

In spite of their gentleness to human beings, Carniolans are very brave in defending their hives against their enemies, such as hornets and wax moths. Unless seriously fought by the bees, hornets in hot countries are capable of wiping out entire apiaries. In a country like Egypt where wax moths prevail, Alpine Carniolans like Mountain Grey Caucasians, but not the varieties from the plains, defend their hives capably.

Alpine strains are less inclined to swarm than those derived from the plains. Tested under semitropical and tropical conditions, they showed remarkable adaptability. Their prolificness requires the use of large hives. With rational manipulation these bees have been used, even in outapiaries of Egypt, with great advantage. So-called Carniolans, crossing with brown bees in the Danube basin or intermingling with yellow bees in the Adriatic area, should be excluded from this classification as they would show defects rather than advantages, and are not true to type.

Carniolan queens are darker than their workers, or more brownish, experience showing that the darker they are the better are their progeny and the more true they are to type. The drones are large and of greyish color with or without visible bands.

### Caucasian Bees

The Mountain Grey Caucasians are a race of bees comparable to the Alpine Carniolans, except for their being smaller in size and for their intense propolizing. In comparative tests, they are generally parallel with the Carniolans or good seconds in their honey production, never third. On the other hand, the somewhat yellow Caucasians from the plains are

comparable to the southern Carniolans, and have many defects, such as temper, swarming tendencies, and weather susceptibilities. They are excluded, therefore, from our strict category of standard bees.

Mountain Grey Caucasians are on a par with Carniolans in comb honey production, as well as in all the qualities afore-mentioned that make "grey" blood most desirable in popularizing modern beekeeping in all sections of the community, including the schools, and in making beekeeping appealing to both sexes.

Caucasians are regarded as comparatively more immune to American foulbrood than other standard bees. Caucasian blood has been observed in the strains of hybrid Italians that are claimed to be excelling in resistance to that disease. However, it is obvious from a biological standpoint that immune strains could be developed through selection from all standard bees.

### Italian Bees

Italian bees are fundamentally the standard bees of America and of many other countries for two reasons: 1. They formerly were available in quantities from their mother country for replacing or for crossing with local honey bees which generally were of the brown race. 2. In addition to their high productivity, their yellow coloring was popular and served as an indication of purity of stock, or of crossing with dark bees.

According to Wagner,[1] the first importation of Italian bees to another country was attempted by Captain Baldenstein as late as 1843. Soon afterwards the "star" of Italian bees began to rise inasmuch as they were afforded in the U. S. A. the finest facilities in a bee paradise to propagate and improve—until they reached the highest possible degree for their race, both by natural and artificial means.

The whole beekeeping world, where brown or even yellow bees other than where Italians and Cyprians existed, began to be interested in Italian bees and to seek them for replacement or improvement of their local bees. This particularly happened in Britain where the brown bee (so-called "British" as it is so-called "German" in Central Europe) had reigned supreme for so long. The outbreak of acarine disease, or "Isle of Wight," epidemics since the early part of the present century was an additional impetus for the importation into Britain of Italian bees and later of Dutch bees, presumably a conglomeration of pure heather brown bees as well as crosses between them and Italians. The first successful importations of Italian bees to America were made about 1860.

In their homeland, Italians generally have a leather-colored background to the abdomen and are three banded, although extra-yellow strains of four bands, and rarely of five, occur with dark edgings and yellowish fuzz rings. The extra-yellow bees are more common in America. The queens are

[1]Langstroth, L. L. 1872. *A Practical Treatise on the Hive and the Honey-Bee.* Philadelphia Pa. J. B. Lippincott & Co. pp. 318–326.

often more yellow than the workers, while the drones are darker, although native-Italian queens and all of their progeny often retain their leather-color characteristics.

Italian bees are supposed to be more reliable in their swarming habits, but they are no better or no worse than other standard bees within the meaning of the word. Similarly is the defense of their home against enemies, including wax moths. On the other hand, Italians, in common with other yellow bees, are disposed to robbing and may be a potential menace in a mixed apiary of nuclei in particular. They use propolis freely but not to the extent of Caucasians, and are only fair in accepting new queens. Some strains may be as gentle as the grey bees and as quiet on combs, but the majority are of nervous disposition.

Notwithstanding their excellent qualities, the present leading commercial standing of Italian bees is chiefly one of circumstance and not of peculiar merit. Given equal chances and different conditions, grey bees (Carniolans and Caucasians) would in all probability have been more sought after in past decades owing to their superior qualities.

Nevertheless, Italians in a 6-year comparison with Carniolans, by Gooderham,[2] of Canada, produced 39 per cent more honey than their Carniolan competitors. Whether this was due to the influence of locality or to better strains of bees remains to be shown inasmuch as Alpine Carniolans, in particular, were not used in contrast to selected Italians. On the other hand, Corkins and Gilbert[3] in a 5-year comparison demonstrated the supremacy of Caucasians over Italians, while Park[4] showed, in a 5-year comparison, the supremacy of Carniolans over both Italians and Caucasians, the Italians ranking second in this case.

## Native Bees

From a practical point of view, *first crosses* between standard races of bees are choice utility strains. Similarly, first crosses between standard bees and races indigenous to a country or locality provide useful strains. However, it is essential that yellow bees are not crossed with each other, otherwise such bees in their second or third crosses will degenerate into highly nervous, vicious strains. The correct procedure, therefore, is to make crosses between yellow and dark races, such as crossing Italians with Carniolans, Caucasians, Germans, or Tunisians, and Egyptians with Carniolans or Caucasians.

Under present conditions, the bee population of the world is fundamentally composed of native or local bees. Many decades will pass before such bees could be materially changed through crossing with standard

[2]Gooderham, C. B. 1938. Carniolan versus Italian bees. *Rpt. Dominion (Canada) Apiarist 1934–1936.* pp. 3–4.

[3]Corkins, C. L. and C. H. Gilbert. 1932. A comparative test of the Caucasian with the Italian race of honeybees. *Wyo. Agr. Exp. Sta. Bull.* **186.**

[4]Park, O. W. 1938. Races of bees for Iowa. *Report of State Apiarist. 1937.* pp. 101–110.

bees. It behooves beekeepers operating in African and Asiatic countries, in particular, to study the characteristics of their local races in order to determine the potentialities which they offer in reforming their native beekeeping.

By way of example and demonstration as to practical possibilities, three typical and indigenous races of bees are next discussed, namely brown or German bees, Egyptian bees, and Cyprian bees. These three races of native bees have received more attention in crossing with standard bees than any other races.

### Brown Bees

Native to Central Europe, this race of bees accidentally played an important part in the shaping of modern beekeeping. Reputed as the first race of honey bees to be introduced into America by the Massachusetts Bay Company in 1638, brown bees paved the way, by their contrast in color, for the introduction of yellow Italian bees.

Brown bees proper, as met with in Britain, Germany, and Scandinavia, present different characteristics than the Dutch or their improved cousins, the French bees, in being altogether conservative, in their comparatively small size, in their limited multiplication, in their susceptibility to diseases, and in their succumbing to the ravages of wax moths which are not fought as tenaciously by brown bees as by standard or even Dutch bees. While Dutch bees multiply rapidly and are bent on swarming, brown bees are not at all prolific and are little disposed to swarm. Dutch bees are more inclined to rob than Italians, and are not suited to out-apiaries without frequent supervision.

Altogether, brown bees are not as suited to intensive honey production as are the Dutch or heather bees. In common with the dark races, brown bees build white combs sealed with white cappings and are excellent comb honey builders. They are steady on the combs and are shaken off of them readily, but they are not superior in these qualities to Carniolans and Caucasians, which excel them in their general characteristics.

In color, size, and temperament, brown bees are easily distinguishable from grey bees which are larger, far more docile, and by no means nervous. On the other hand, should brown bees be crossed with grey bees, it may be difficult for the inexperienced to differentiate between the resultant bees and the parent greys, until their temper happens to declare their real constitution, particularly in a second or third crossing. This is likely to happen in those countries where brown bees predominate. Worse results may arise in Tunisia where the Tunisian or Punic bee (*Apis nigra*) is noted for its ferociousness, as endorsed by Harker,[5] former secretary of the Apis Club and assistant editor of *The Bee World,* from experiences in England.

---

[5]Harker, Leonard S. 1938. *Blazing the Trail. Reminiscences of A. Z. Abushâdy.* London. The C. W. Daniel Co., Ltd. p. 43.

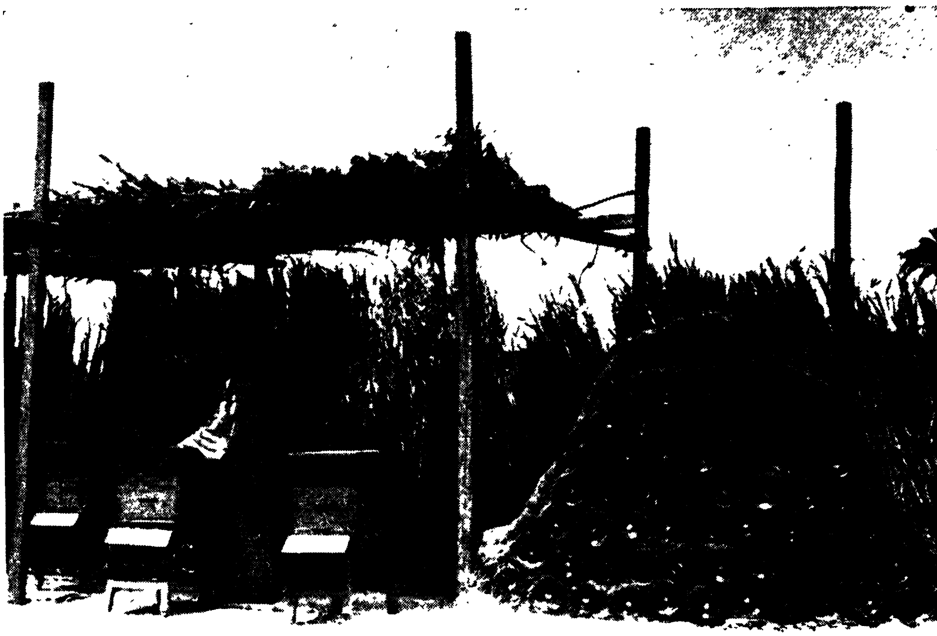


FIGURE 3. A co-operative apiary in Girga Province, Upper Egypt, showing old-fashioned tubular hives (stacked in pyramidal form) side by side with modern Langstroth hives. The beekeeper is wearing an "overall" with a gauze veil stitched to the head part. Such attire is deemed necessary when working Egyptian bees. (*Photo courtesy Dr. A. Z. Abushâdy*)

## EGYPTIAN BEES

Distinguishable from Italians by their light yellow bands and smaller size, Egyptian bees are better differentiated by the whitish creamy fuzz which is traceable in all Egyptian "blood" and is clearly noticeable in Egyptian-Italian crosses. Perhaps the prettiest hive bee in existence, the Egyptian bee gives issue to a no less pretty, yet far more industrious, bee in the famous Carnio-Egyptian bee, the result of crossing between Carniolans and Egyptians. The first cross between the two races is indeed a choice one, being equal to Carniolan Italians or Caucasian Italians in productivity and more appealing aesthetically.

The present Egyptian bee (*Apis fasciata*) is the recognized descendant of the Pharaonic bee kept by the ancient Egyptians many centuries ago. Inasmuch as the honey bee was held in sacred esteem by them, it spread with the extension of the Egyptian Empire and influenced the honey bees of countries bordering on Egypt. However, it had no access to the Italian bee and, contrary to prevailing statements, does not appear to have had any effect on that race in its mother country. Egyptian blood is too conspicuous to be masked even in distant generations. The pure bees have a distinct high flight tune not shared by other races of bees.

Generally of nervous disposition, like all yellow races, and often not of good temper, Egyptians, like Syrians, nevertheless present certain strains that are comparatively docile. These tolerable strains are suited for breeding, not so much for keeping the race pure as for breeding crosses with standard grey bees. In the writer's opinion, Egyptian queens mated to grey drones, or grey queens mated to Egyptian drones, give rise to satisfactory progeny, both industriously and aesthetically, in their first crosses. They are commercially attractive and are productive bees.

Being very prolific, though not expanding spontaneously into large colonies instead of swarming excessively, Egyptians are most suitable for nuclei used for breeding queens of Egyptian-grey crosses, by curtailing the production of yellow drones and flooding their breeding apiaries with grey drones abundantly raised for the purpose. Artificial queen rearing is not necessary with Egyptians because they build large numbers of queen cells which may be counted by the hundreds in any colony during the swarming season. Such queen cells could be turned to advantage by the queen breeder who aims at cross-fertilization.

Egyptian queens are comparatively long and slim, and have a reddish bronze tinge which is quite characteristic. This color characteristic in the queen, as well as the whitish creamy fuzz of the workers, makes Egyptians easily discernible. Compared to the size of her colony, the queen is prolific, but instead of her bees expanding into strong colonies, they prepare to swarm at half-strength or less than that of a normal colony. After their prime swarm, they send out many afterswarms accompanied by numerous virgins, which ultimately will be liquidated to the normal one queen with each swarm. However, these numerous free-flying virgins are a menace to an apiary containing standard bees because of their agility and tenacity in entering other hives and killing the queens.

Pure Egyptians are good honey producers in comparison to the size of their colonies, but they are not suited for comb honey production. However, from a national economic standpoint, Egyptians make a poor showing just as do Syrian, South African, Indian, and similar races of honey bees. Such bees may be regarded as hive bees of temporary necessity, their real advantage lying in providing raw material for suitable crosses with standard bees. Among their good qualities are their staunch defense of their hives, their disinterest in propolization, their economic consumption of stores, and their adaptability to seasonal variation.

Among their defects are the development of fertile workers, their unsuitability for outapiaries because of their erratic swarming habits in which they rival or even exceed Dutch bees, their excessive nervousness which makes them roam all over the combs or "boil over" when subdued by smoke, their viciousness if not subjugated demanding a "smoking assistant" during manipulation, their strong inclination to rob, as shared by Italians, Cyprians, and by many other yellow races, and their great opposition to queen introduction.

Egyptian bees had the honor of importation into America, as early as 1886, by none less than Langstroth, but the grave mistake was committed in trying to propagate them pure intsead of utilizing them for cross-breeding, thus quickly leading to their unpopularity.

Owing to strict quarantine, no infectious bee diseases are known in Egypt and, therefore, no data are available as to the degree of their natural immunity. Testing them under British conditions, the writer did not find them more immune to bee diseases than standard bees.

## CYPRIAN BEES

Except for their slightly smaller size to the discerning eye, Cyprian bees in general external appearance may well be taken for Italians, at least as long as no careful examination is made of the underside of the abdomens which are marked by orange or yellow as compared with Italians. They usually show a yellow crescent at the base of the thorax. The writer has not been able to find further discriminating marks as pronounced by authors and claimed even by Benton.[6]

Cyprians are highly prolific, industrious, and fine honey gatherers. At one time they were used by the Egyptian Ministry of Agriculture to improve the local bees through cross-breeding. The choice was not appropriate because the Cyprian-Egyptian bee, a cross between two yellow races, was more spiteful than the parent stock and was as vicious as Tunisians. Later, in 1930, the Bee Kingdom League was responsible for introducing and propagating Carniolans in Egypt,[7] leading to the evolution of Carnio-Egyptian bees which have gained great popularity, and with them the Langstroth hive was adopted as the standard hive of Egypt. In the grand exhibition of the Royal Agricultural Society of Egypt which was held in 1926, Cyprians were a very bad advertisement for beekeeping as they had to be watched from a great distance, in contrast to the exhibition of Alpine Carniolans a few years later.

They are as bad as Egyptians and other Middle Eastern races, such as Palestinians and the "Sayyafy" Syrians, in the development of fertile workers immediately after queenlessness and sometimes in the presence of the mother queen. They are as bad in their robbing activities and in balling their queens through erratic excitement or disturbance, particularly should the honeyflow suddenly stop or during robbing, stormy weather, or irritating dry heat. Their good foraging qualities are countered by the time-consuming management which they require and by the total discomfort of the honey producer.

Their queens are smaller, more slender, and generally darker than Italian queens, with perhaps some orange-yellow coloring. Some queens are even smaller than Egyptian queens.

---

[6]Benton, Frank. 1879. The next progressive step. *Amer. Bee Jour.* **14**(11):507–511.

[7]1931. Royal Agricultural Society of Egypt. 14th exhibition in Cairo. *The Bee Kingdom* 2(3):71-72.

In introducing Cyprians to American beekeepers as early as 1880, the same mistake was made as in introducing Egyptians a decade earlier, namely to advocate their use in pure form as a progressive step. In their turn they soon fell into disrepute.

## Conclusion

In this chapter, no attempt has been made to give an academic or systematic description either of the known races of bees or even of those selected as of typical commercial value. Such an academic description is of no significance to the practical apiarist, and is more appealing to the entomologist. On the other hand, directing light has been shed on the proper status of the various races of honey bees, the present roles which they are playing through man's influence in creating still better bees, and the most practical course to be followed in making the best of available races. The following conclusions have been substantiated and bear emphasis:

1. The progress of bee culture depends on utilizing standard bees which are fundamentally three races: Carniolans, Caucasians, and Italians. The first two are of grey blood which, in the opinion of the writer, is more desirable, while the third is the choice yellow blood available in the beekeeping world, notwithstanding peculiar merits of some native bees.

2. From the standpoint of honey production and as a speedy practical measure, it is imperative by way of a transitory step to utilize native bees after crossing them with one of the standard races. Where native bees are brown or black, Italians are the choice for crossing. On the other hand, where native bees are yellow, then Carniolans or Caucasians are to be chosen for cross-breeding. To get the best possible results, only *first crosses* should be championed, otherwise the bees will degenerate both in productivity and temper.

3. Many of the critical and degrading remarks levelled at standard bees are utterly unjustified and are completely misleading to the craft. By way of illustration, mention may be made of Austrian and Banat bees which have been mislabeled commercially as Alpine Carniolans. The writer has crossed such races with Egyptians and with good results, but not comparable to those of Carnio-Egyptian crossings.

4. Through the creation of isolated queen-rearing stations, apart from artificial insemination, it is quite possible, as accomplished in Egypt, to raise in various countries their particular requirement of standard bees, in view of the shortage of supplies from the mother countries. This applies particularly to Alpine Carniolans and to Grey Mountain Caucasians.

5. False patriotism should not be attached to local bees or to national hives, a practice unfortunately noticeable in some countries, inasmuch as the advancement of the economic interests of beekeepers depends on scientific facts and practical results which support the claims of standard bees.

# III. *The Honey-Bee Colony —Life History**

BY O. W. PARK†

THE fundamental truth of the Biblical statement, "No man liveth unto himself alone," applies to the lower forms of animal life as well as to mankind. No life can exist without producing profound changes which, sooner or later, affect some other life. The living world is made up of endless relationships, both simple and complex. So in beginning the study of any given form of life, it would seem to be worth while to consider some of the relationships that exist between that form and others, particularly with those to which it is most akin.

## Ancestry of Bees

The most ancient records of life—fossil forms and specimens preserved in amber from prehistoric ages—reveal little about the ancestry of bees. Such records, however, do show that, ages ago, the honey bee already existed in much the same form as today. In this connection, a glance at the family tree of animal life may be of interest.

### Zoological Classification

Modern zoological classification, based as it is upon structure, not only is useful as a convenient cataloguing system, but also is significant because it indicates evolutionary relationships. It is, in short, a family tree of animal life. Its primary branches, called *phyla,* give off secondary branches known as *classes.* These in turn divide and subdivide again and again into the successive categories called *orders, families, genera,* and finally *species,* which for our purpose are represented by the smallest twigs.

Like many another weather-beaten tree of great age, it is ill-shaped and unattractive. Not far above its base the gnarled and twisted trunk divides and from this point two trunks arise, one terminating in man and

*Publication of the Iowa Agricultural Experiment Station, Ames, Iowa.

†O. W. Park, Ph.D. Research professor of apiculture, Iowa State College. Formerly assistant in zoology, Kansas State College. Formerly associate in entomology and apiculture, University of Illinois. Specialist in studies on the acquisition of food by the honey bee, activities of the honey-bee colony, and resistance to American foulbrood.

the other in the social insects, such as ants, wasps, and bees. The first mentioned is slender with relatively few branches, while its twin is massive and displays numerous branches of all sizes and descriptions. The largest and by far the bushiest branch on the tree is a giant primary that arises from the more massive of the twin trunks and rears its bushy head high in competition with the more slender trunk whose topmost bough we are pleased to think of as representing mankind. In large letters the giant primary is labeled ARTHROPODA, and on its principal branch, in letters somewhat smaller, we read Hexapoda or Insecta.

Upon the entire tree are perhaps a couple of million twigs, each of which represents a different species. Of this total one million represent insect species. Throughout this luxuriant growth there are, however, occasional bare spots where twigs and smaller branches are sparse or lacking altogether. The branch that represents honey bees is an example. Bees of all kinds account for an estimated 20,000 twigs of which honey bees contribute but four. Thus, high among the topmost boughs, the slender honey-bee branch stands stark and all but naked among its bushy neighbors. All in all, the family tree of animal life presents a lopsided, scraggly appearance.

Of its 15 or 20 primary branches (*phyla*), we shall restrict our attention to the large one labeled Arthropoda (jointed appendages). From it spring about half a dozen secondary branches (*classes*), one of the uppermost of which, as already mentioned, is named Hexapoda (six-footed). It gives off about 25 smaller branches (*orders*), the upper one of which is labeled Hymenoptera (marriage on-the-wing*). This one divides into nearly a dozen parts (*superfamilies*) and one of them, the uppermost, is called Apoidea (bees). It in turn subdivides into half a dozen still smaller branches (*families*) among which we find one near the top that is marked Apidae (bees). This gives off but a single small branch (*genus*), tagged Apis (bee), and from it arise just four twigs (*species*). The tags on the three lowest say: *dorsata, florea,* and *indica,* while to the topmost is attached a label that is somewhat blurred, as if by a partial erasure and a changed spelling. It is possible however to make out the original spelling as *mellifera* (honey carrier), while the more obvious lettering reads *mellifica* (honey maker).

As illustrated by the branching and rebranching of this tree of animal life, lobsters, crayfish, centipedes, spiders, mites, ticks, insects, and all other animals of the phylum Arthropoda are regarded as more closely related to each other than to the animals of any other phylum or subdivision thereof. And while *Apis mellifera* (*or mellifica*) is more closely related to a fly or a grasshopper than to a lobster, it is yet more akin to

*Because the insects of the order Hymenoptera, which includes the honey bees, typically mate in flight, this translation is far more distinctive than *membranous wings*, which had been widely used heretofore. *See*: Nabours, Robert K. 1945. The derivation of Hymenoptera. *Ann. Ent. Soc. Amer.* **38**:457.

a bumble bee and still more so to other species of honey bees. Thus modern zoological classification expresses the degree of structural resemblance and thereby genetical relationships.

ZOOLOGICAL CLASSIFICATION OF THE HONEY BEE

| | |
|---|---|
| Kingdom | Animal |
| Phylum | Arthropoda |
| Class | Hexapoda or Insecta |
| Order | Hymenoptera |
| Family | Apidae |
| Genus | Apis |
| Species | *mellifera* |

Scientific name, *Apis mellifera* L.

Since two scientific names for the honey bee are found in the literature, an explanation is in order. Linnaeus, the originator of the binomial system of nomenclature, at first used the name *Apis mellifera,* meaning *the honey-carrying bee,* but subsequently changed to the name *Apis mellifica, the honey-making bee.* The latter, an accurately descriptive name, appears almost exclusively in literature published prior to the beginning of the 20th century when the law of priority in scientific nomenclature was established and the 10th edition of Linnaeus' "Systema Naturae" came to be recognized by taxonomists as final authority on all scientific names that appeared therein. It is unfortunate that Linnaeus had not yet changed to the correctly descriptive name for the honey bee in 1758, when his tenth edition was published, for confusion has now arisen because taxonomic purists insist on the use of *mellifera,* as given in that edition, while many zoologists and beekeepers have continued to use the truly descriptive name, *Apis mellifica.* But now that *mellifera* is indicated by the current usage[1] of the American Association of Economic Entomologists and the Entomological Society of America, as well as by that of the Division of Insect Identification of the U.S. Bureau of Entomology, it is deemed logical to forget our personal preferences and follow the united leadership of these representative agencies.

*A. mellifera* has been widely distributed throughout the world by man and was introduced into this country from Europe by the early colonists. All three of the other known species of honey bees are restricted to the region of India and the Malay peninsula. Colonies of *A. dorsata* and *A. florea* build but a single comb in the open, suspended from a branch or some overhanging ledge, and do not respond favorably to man's attempts at cultivation. *A. indica,* like *A. mellifera,* nests in cavities and will use hives when they are provided. Some authorities consider it probable that this species is a variety of *A. mellifera.*

Bees, wasps, and ants are so similar in many respects that there can be little doubt of their common ancestry, but their food habits differ markedly. Bees of practically all kinds provision their nests with pollen

---

[1]Muesebeck, C. F. W. 1946. Common names of insects approved by the American Association of Economic Entomologists. *Jour. Econ. Ent.* **39**:427-448.

or honey or both; whereas most wasps provision theirs with "meat" in the form of other insects or spiders. Ants with some exceptions are general feeders, making use of materials of both animal and vegetable origin. Many feed on exuding sap, honeydew, and the nectar of plants.

## SOCIAL INSECTS

In the order Hymenoptera are to be found all of the social insects except the so-called white ants, or termites. Social insects, as the term implies, are so named because numerous individuals build and maintain a common home. All true ants, some wasps, and a few bees have developed this advantageous way of life (Figs. 4, 5), and in all three groups the basis for colony life is very similar.

The many species of bees differ widely in habits: some are solitary, each mother providing a nest for her offspring; some are inquilines or cuckoo bees, usurping the nests of others; while a very few are social. Various stages in the development of community life are to be found among different species of bees, from rudimentary beginnings in some of the so-called solitary bees up through a number of intermediate forms to the honey bee.

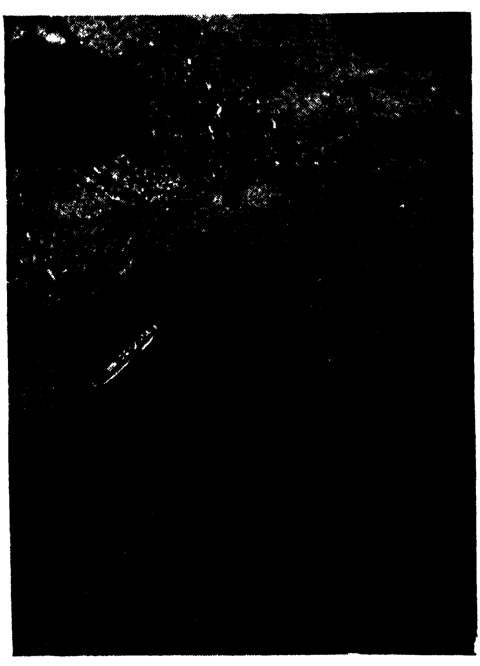
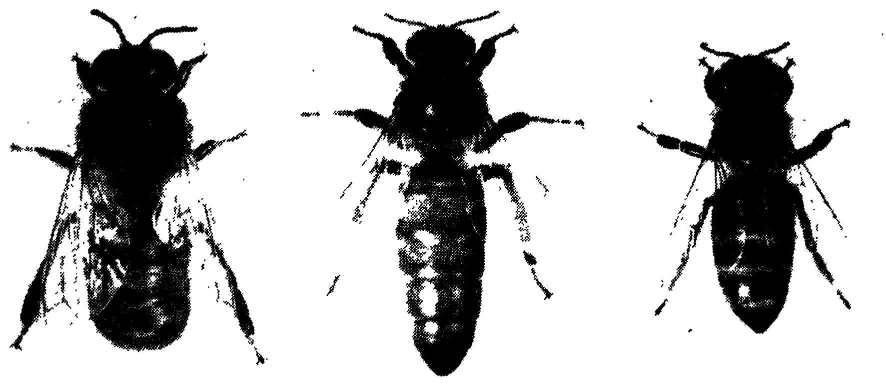


FIGURE 4. These craters and many more not shown mark the numerous entrances to the subterranean nest of this strong colony of Texas ants, *Atta texana*. The knife at left of center denotes the relative size. (*Photo by O. W. Park*)

FIGURE 5. A colony of honey-wasps of the genus *Nectarina* whose food habits and mode of life closely resemble those of the honey bee. The nest of a populous colony as this one measures about a foot in diameter. (*Photo by O. W. Park*)



a. b. c.

FIGURE 6. a, Drone; b, Queen; c, Worker. Enlarged slightly. (*Photos by O. W. Park*)

In the colonial forms, insect life shows its highest type of development, as indicated by extreme specialization in structure and habits, and by the inability of the individual to maintain itself. Alone, a single honey bee is almost as helpless as a new-born child, being numbed by the chill of a cool summer night, but, as a component part of a colony, it is able to withstand the rigors of severe winter weather for extended periods. Outstanding social development places the honey bee at the top of the bees and perhaps of all insects.

## Colony Life

Colony life is based upon division of labor accompanied by corresponding specialization and adaptation. Sex, naturally enough, forms the basis for the most fundamental division of labor in all animal communities. In the honey-bee colony there are three castes: drone, queen, and worker (Fig. 6a, b, c), of which the last two are female and the first, male. Normally a colony comprises one queen, many thousands of workers, and, at certain seasons of the year, some hundreds or even thousands of drones. The queen is specialized exclusively for the production of eggs, the workers as "wet nurses" and general laborers, while the sole function of drones is to mate with the young queens. Within the ranks of the workers, as is now known, the age of the individual is the broad fundamental basis for performance of the various duties. Hence, the most efficient colony would be one that contains balanced numbers of workers representing all ages.

In their structure and instincts, honey bees have become so highly specialized that no individual is capable either of maintaining itself (for any extended period) or of perpetuating the species. Even the duties of motherhood are divided. The queen, therefore, is not, as has been stated

by various writers, a *perfect* female. While she is magnificently adapted for the production of eggs, she is in no way fitted for nursing her young. On the other hand, a normal worker (see "Laying Workers" in this chapter) is equipped for nursing the young, but is incapable of laying eggs. Thus, neither the queen nor the individual worker alone can reproduce the species, and of course, the drone is unable to do so. The species, therefore, can be reproduced only through appropriate interaction of the several pertinent relationships for which queen, worker, and drone are peculiarly fitted.

### The Nest of the Honey Bee

Honey bees, when left to their own devices, make their homes in almost any available cavity. Occasionally they build outside under some sheltering ledge, or even in the open among the branches of a tree. While hollow trees and walls of buildings seem to be favorites, bees do not hesitate upon occasion to commandeer a discarded washing machine or an old stove. Such homes, however, usually are not considered hives, that term being applied more particularly to those habitations intentionally provided for bees.

Contrary to popular opinion, honey bees kept in hives are no more domesticated than those to be found in a hollow tree deep in the forest; and, conversely, any swarm that absconds from a modern apiary is as much at home in a pathless jungle as are those bees that have lived there always. Both are guided by instinct in practically all that they do. Bees react to a given stimulus in a given way whether they live in a nicely painted, movable-frame hive in your own back yard or under a rock ledge in a desert. The habits and instincts of honey bees have in no way been changed by their long association with the human race; so, regardless of where they live or the kind of habitation they use, the over-all plan of the nest they build follows a universal pattern, infinitely varied in minor details.

The nest comprises a number of combs, about half an inch apart, made up of hexagonal cells with which most of us are familiar in that delectable product of the beehive, comb honey. The bees construct these combs of beeswax, a product of their own bodies, usually building downward from the upper side of the cavity or, in modern hives, from the top bars of certain hive units called frames. In the cells of these combs, bees raise their young and deposit their stores. Cells are of two principal sizes, known as *worker* and *drone* cells in accordance with the type of individual normally reared therein, and, just as drones are larger than workers, so also are the cells in which they grow to maturity. Measuring along a row of cells, it will be found that there are about four drone or five worker cells to the linear inch. While cells of both sizes are used for the storage of honey, bees instinctively construct storage combs almost exclusively of drone-size cells when building according to their own design.

On the contrary, pollen rarely is stored anywhere but in worker cells. Cells in which queens are reared are constructed especially for each such occasion and are dismantled soon after the queen has emerged. They are large cells of an entirely different design and will be described later.

When laying, the queen deposits a single egg per cell (Figs. 7, 21, 27, 28), affixing it by one end near the center of the cell base. From the egg there hatches a tiny larva which, after a period of rapid growth, is transformed into a pupa that gives rise to the adult, following a quiescent period. The young of the bee, prior to emergence as adults, are known collectively as *brood*. The term may include not only the egg, larval, and pupal stages but also young adults ready to emerge from their cells. For details on transformations from egg to adult see "Developmental Stages" in this chapter.

Since cells containing brood are capped over by the bees just prior to the end of the larval period, beginners sometimes do not at first distinguish between capped brood and capped honey, but they differ sufficiently in appearance to permit recognition at a glance by anyone having even a little experience or proper information (Fig. 8). In general, combs are nearly white when first constructed and change very little in color if used only for the storage of honey, but combs used for the rearing of brood soon take on a light-brown appearance. They continue to darken with use and eventually become almost black due to the accumulation of excreta and cast skins left by the larvae. Except in the case of brand new combs, brood cappings are constructed largely of bits of wax taken from

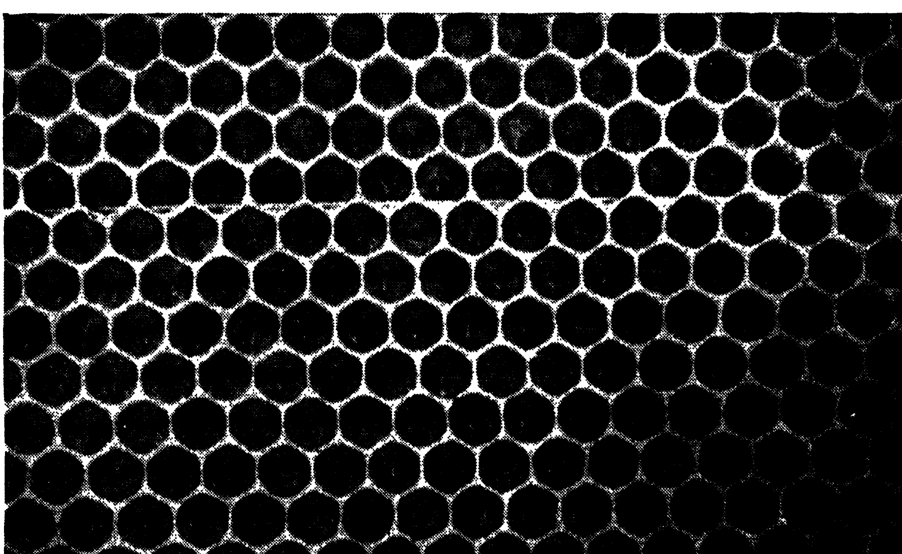


FIGURE 7. Newly constructed comb having worker-size cells is nearly white. Note tiny white eggs, one in each cell. About 1½ times natural size.

FIGURE 8. Brood cappings, seen in the central area, differ noticeably from honey cappings showing in the upper third of comb. (*Photo by O. W. Park*)

various parts of the same or perhaps an adjacent comb, combined in such a way as to provide a porous covering through which the developing insect can breathe. Brood cappings vary in color with that of the individual comb, but usually are some shade of brown and have a duller appearance than the cappings which cover cells of honey. Cappings over new honey usually are made largely of new wax and are, therefore, nearly white, except that honey stored in old brood comb may have dark cappings which sometimes are not easily told from brood cappings. Healthy worker brood and honey cells have cappings that are nearly flat or only slightly convex, while drone brood has definitely convex cappings which give a bullet-nose appearance (Fig. 9).

Cells never are completely filled with pollen, and are not capped unless the cell is first filled with honey on top of the pollen. Pollen so stored will keep indefinitely, for honey is an excellent preservative for pollen. Combs containing considerable amounts of pollen preserved in this manner are especially valuable to the bees as a source of nitrogen for the production of brood in late winter and early spring before fresh pollen becomes available.

Natural homes of bees found in rock cavities and in hollow trees show the characteristic arrangement of the nest, so a study of them helps us to understand how man can supply hives designed in conformity with the habits and instincts of the honey bee. As already indicated, combs are used both for the rearing of brood and for the garnering of stores. While the same cells may be used at different times for either purpose, there is

a region usually located at or near the bottom of the central comb mass, which is devoted primarily to the rearing of brood during the active season, and in consequence is known as the brood nest. The space occupied as the brood nest is more or less spherical in shape and usually includes circular or elliptical areas of brood on each of several adjacent

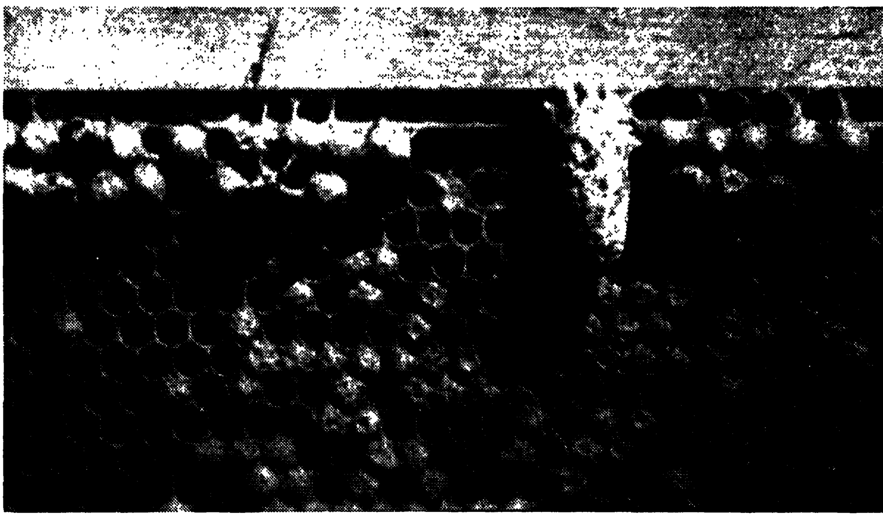


FIGURE 9. Sealed brood. A sealed queen cell hangs from the top bar, flanked on either side by drone brood with characteristic bullet-nose cappings while worker brood is developing in smaller cells under cappings that are but slightly convex. Slightly less than natural size. (*Photo by O. W. Park*)

FIGURE 10. Comb of brood showing typical arrangement of brood, pollen, and honey areas. (*Photo by O. W. Park*)

combs which usually are parallel though not necessarily straight. The larger ones of these brood areas are located near the center with adjacent areas on either side progressively smaller as one approaches the lateral limits of the brood nest. Bordering the brood area on each comb, especially above and at the sides, there usually is a band of cells about 1 or 2 inches broad (Fig. 10), occupied by "beebread," or stores of pollen, to which the bees have added a little honey as a preservative. Immediately beyond this band of pollen cells on each comb of brood begins the region of honey stores, from which must come the beekeeper's profit, if any. Practically all hives now used commercially are composed of two basic units known as brood chambers and supers, which may or may not be identical in size and design. The brood chamber, which may be either a single or double unit, is intended to provide adequate room for brood rearing plus the usual stores of pollen and a moderate amount of honey stores for use by the colony. Supers are units for the storage of the surplus honey which the beekeeper takes as pay for the care he gives his bees. By adding or removing supers, the beekeeper is able to increase or decrease the amount of storage space in accordance with the needs of the colony.

## The Queen

The one large bee of peculiar shape to be found in every normal colony of bees is the mother bee, commonly called the queen (Fig. 11). She is considerably larger than a worker and longer than a drone, though not nearly so broad. Her wings are much shorter in proportion to her body than are those of either drone or worker, but in reality they are longer than those of a worker. Because of her long tapering abdomen, she appears more wasplike than other inmates of the hive. The curved sting, which she reserves for use against rival queens, being only slightly barbed, can be withdrawn and used repeatedly. Though upon occasion she can move with astonishing quickness, her motions generally are deliberate and decorous. No colony can long exist without this all-important member.

Throughout the ages, naturalists have devoted much attention to honey bees, but the matter of their sexes remained in doubt until comparatively recent times. Aristotle and other ancient authors used the term "king" to designate the one large individual considered to be the ruler of the colony. The idea that the "King Bee" is a female was not wholly unfamiliar to ancient authors, however, for Aristotle[2] wrote: "By some they are called mother bees, as if they were the parents of the rest; and they argue that unless the ruler is present, drones only are produced and no bees (workers). Others affirm that they have sexual intercourse and that the drones are males and the bees (workers) females."

[2] Aristotle. 1907. *History of Animals*. Trans. by Cresswell. p. 128.

FIGURE 11. Queen and worker. Enlarged 4X. (*Photo by O. W. Park*)

In 1609, Charles Butler, an English beekeeper, published his long-famous treatise on bees, under the title, *Feminine Monarchy,* wherein he proclaimed that the "King Bee" is in reality a "Queene." From a careful study of his book, it seems apparent, however, that Butler thought of her only in the capacity of ruler of the "feminine kingdom" and progenitor of daughter queens, but not at all as the mother of the workers and drones. The anonymous author of *Traite Curieux des Mouches a Miel* (Paris, 1734) mentions the "King Bee" as the mother of all the others. This latter concept of her role in the hive had been established, prior to 1680, by Swammerdam[3] who ascertained the sex of bees by dissection, and to whom most likely belongs the credit for having been the first to demonstrate conclusively the sex of the queen bee.

A brief extract from the celebrated Dr. Boerhaave's *Memoir of Swammerdam,* showing the ardor of this naturalist in his study of bees, should put to blush the arrogance of those superficial observers who are too wise to avail themselves of the knowledge of others:

This treatise on bees proved so fatiguing a performance that Swammerdam never afterwards recovered even the appearance of his former health and vigor. He was most continually engaged by day in making observations, and as constantly by night in recording them by drawings and suitable explanations.

His daily labor began at six in the morning, when the sun afforded him light enough to survey such minute objects; and from that hour till twelve, he continued without interruption, all the while exposed in the open air to the

[3]Swammerdam, Jan. 1737. *Biblia Naturae.* Leyde (Leyden).

scorching heat of the sun, bareheaded, for fear of intercepting his sight, and his head in a manner dissolving into sweat under the irresistible ardors of that powerful luminary. And if he desisted at noon, it was because the strength of his eyes was too much weakened by the extraordinary afflux of light, and the use of microscopes, to continue any longer upon such small objects.

He often wished, the better to accomplish his vast, unlimited views, for a year of perpetual heat and light to perfect his inquiries; with a polar night, to reap all the advantages of them by proper drawings and descriptions.

Swammerdam's discoveries left no room for doubt either as to the sex of the "King Bee" or as to the origin of the other bees of the colony. Naturally then, the mother bee came to be known as the queen, although she in no way governs.

Whatever may be the governing force of the colony, it most certainly is not the queen. A colony composed exclusively of workers that never had any contact with a queen, if supplied with combs containing eggs or young brood, will, in an orderly and efficient manner, perform successfully all the functions normally performed by workers in a queenright colony, except for such duties as are involved directly with the feeding and care of a queen. Even in a normal colony, the workers, to a considerable degree, control the extent of egg laying, and circumscribe, if they do not actually determine, certain of the activities of the queen. Mentally less highly developed than the workers, she is little more than a slave, an automaton—in short, an egg-laying machine.

In this capacity, she performs with such efficiency that, during the height of the brood-rearing season, her daily output of eggs often exceeds her own weight which, on account of the developing eggs in her ovaries, is then about double what it is outside the breeding season. While some queens, under special conditions, may be capable of laying more than 3500 eggs in a day, brood counts made by Nolan[4] and others indicate that an average rate of 1500 to 2000 per day for a period of more than 10 days should be considered extra-good, even during the height of brood rearing. Queens lay most heavily in late spring and early summer, prior to and during the honeyflow, and very little during late autumn and winter.

Queens are reared only under one of three conditions: queenlessness, supersedure, and swarming. Sudden loss of their one and only queen constitutes a major emergency in the beehive for, without a queen or the means to provide one, the fate of the colony is sealed. Usually, however, there are at hand the means whereby the colony is able to provide a queen for itself and thus escape certain doom. When a queen fails noticeably in her laying because of age, injury, or some other reason, the workers proceed to rear a daughter queen that soon replaces the failing mother. This is spoken of as supersedure, and constitutes the normal procedure whereby a colony is able to maintain indefinitely a succession

[4]Nolan, W. J. 1925. The brood-rearing cycle of the honeybee. *U.S.D.A. Bull.* **1349.**

of queens without any multiplication of colonies. Swarming, on the other hand, involves the multiplication of colonies through division, together with provisions for the production of additional queens.

Theoretically, and barring accidents and other exigencies, every honey-bee colony in the world today could maintain perpetual existence since, through repeated supersedure of queens, the reproduction of workers and drones, as well as of queens, could continue forever. In reality, however, accidents and other exigencies do result in the extermination of many thousands of colonies annually, so that, without some provision for increasing the number of colonies, the species would become extinct in a remarkably short period of years. The implications involved in such a situation would be far-reaching if not, indeed, disastrous for the human race. No doubt humanity could exist without either honey or beeswax, but consider the innumerable orchard, garden, and field crops that would produce little or nothing without the pollinating services of the honey bee. Fortunately the honey-bee colony has been endowed with an instinct which, from time to time, brings about an increase in the number of colonies. Swarming is Nature's provision for the reproduction of colonies as distinguished from the reproduction of individuals (Fig. 12). Two kinds of reproduction, therefore, must occur in the honey bee if the species is to maintain itself or show any increase in the number of colonies.

FIGURE 12. Swarming is Nature's provision for the reproduction of colonies as distinguished from the reproduction of individuals. (*Photo by O. W. Park*)

## How Queens Are Produced

Queen bees develop in special large cells which are constructed as required for immediate use and are dismantled shortly after being vacated; hence they are not to be found at other times. Dismantling often stops short of complete removal, leaving a queen-cell "button" that looks like a small acorn cup. As may be observed from the accompanying illustrations (Figs. 13 to 20), queen cells vary considerably in external appearance, but in general they are about an inch long, somewhat larger at the base than at the tip, and many of them, because of the sculptured surface of their thick walls, look somewhat like the shell of a peanut.

Queen cells, in contrast to the horizontal position of worker and drone cells, always hang downward, presumably to economize space, for the distance between combs is too small to accommodate their length without serious interference with cells opposite them. Often they are built on the edges of combs where space is most readily available, as shown in Figs. 13, 14, and 17; but frequently they are built on the face of a comb, as illustrated in Figs. 15, 16, and 18. In such instances the bees commonly reduce the depth of other cells in close proximity to the queen cell.

Figure 13. Worker bees constructing a queen cell on the lower edge of the comb. The bee in center appears to be looking into the cell to determine what next is needed—wax or royal jelly. ("*Honey Bee*," *Encyclopædia Britannica Films Inc.*)

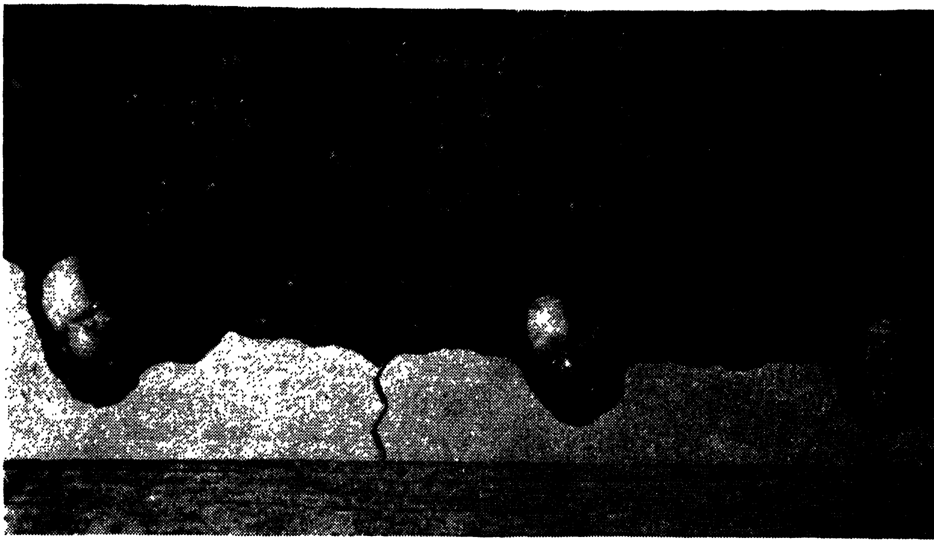


FIGURE 14. Royal pupae of different ages exposed in their cells. Enlarged 1½X. (*Photo by O. W. Park*)

When in the process of constructing queen cells, the worker bees give them an unusual amount of attention. They are continually peeping into them and, as soon as one is satisfied, another pops in her head to note progress or to increase the supply of royal jelly (Fig. 13). With so much attention centered on them, one may readily infer that they are indispensable to the welfare of the colony.

The number of queen cells in a hive varies greatly, depending upon the race and strain of bees and upon the nature of the instinctive impulse under which they are constructed. Bees of Italian and Caucasian races are less given to the production of large numbers of queen cells than are some of the others. Some strains of Carniolans produce royal cells in considerable numbers, while other strains of the same race apparently produce them in greater moderation. Under the swarm impulse, Cyprian, Syrian, and Egyptian races sometimes produce a hundred or more queen cells, but such cases are rare in other races.

When constructed under the supersedure impulse, only a few queen cells are built, seldom more than two or three and sometimes only one; whereas, under the swarming impulse, the number is apt to be not less than five and occasionally more than a dozen, although in certain races it may be much higher. Under the emergency of sudden queenlessness, the number is more variable but usually there are three or more.

Royal cells are not all begun at the same time so in case one or more of the older cells fail to produce a queen, still other potential mothers usually are in the making. The instinct responsible for this wise provision obviously is one of Nature's numerous safety measures designed to insure the continuation of the species.

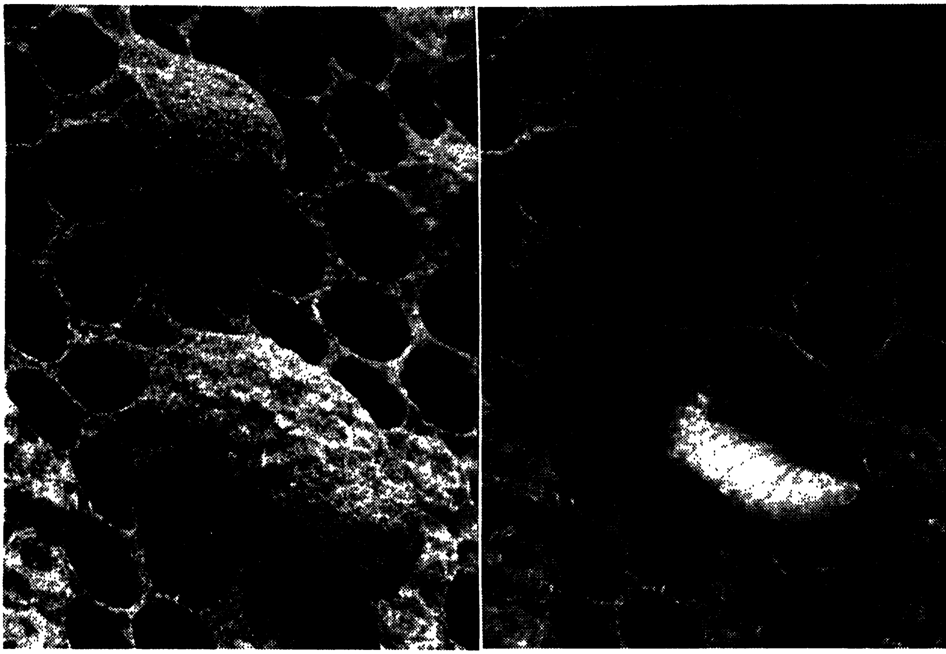


FIGURE 15. A postconstructed queen cell. Left, exterior. Right, interior showing connection with cavity of worker cell, also a mature queen larva. (*Photo by O. W. Park*)

"Male" and "female" eggs are produced by every normal mated queen. The manner in which they differ and how that difference arises will be discussed later under the topic "Parthenogenesis." "Male" eggs develop into male bees, called drones, while "female" eggs develop into females, of which there are, as already stated, two kinds, queens and workers. Undoubtedly there was a time in the evolution of the honey bee when there were but two castes, males and females, just as today among the solitary bees. Since that time, both males and females have changed greatly. The drone can no longer maintain himself as he did then, while the duties of motherhood have become highly specialized and divided between the two types of females, each of which is the perfect complement of the other but neither, alone, a perfect female. As previously stated, the queen is highly efficient in the production of eggs but no offspring would arise from the hundreds of thousands of eggs she lays during her lifetime, were it not for the food, shelter, and solicitous care provided by the workers. Perhaps it should not be considered too strange, therefore, that the egg which is destined to become a queen does not differ in the slightest particular from the egg intended to become a worker; yet the only established causes for dissimilarity in the course of development of these two castes are differences in the food provided during the larval growth period, and in the respective types of cells which encase them.

Future investigations may reveal some other differences, for, as has been stated by Dr. John Anderson[5] of the North of Scotland College of Agriculture: "This differential development increases the mystery, and cannot be explained on any simple space-and-food theory."

Since worker and queen cells have been described already and their principal points of difference noted, we may proceed to a consideration of some nutritional aspects of the differential development of queens and workers from identical eggs.

"Royal jelly" is the popular name for the food supplied throughout their developmental period to larvae destined to become queens (Fig. 15, right). It is a highly nitrogenous food now generally conceded to be of glandular origin (see Chapter XIX, "The Anatomy of the Honey Bee"). When fresh, royal jelly is milky white and the consistency of cream but, upon drying a little, becomes a gummy paste of a slightly yellow color. Under favorable conditions, the nurse bees that produce this potent food furnish it to queen larvae in such great abundance that an unused portion the size of a pea frequently may be found in the base of a cell just vacated.

The younger worker and drone larvae likewise receive royal jelly (Fig. 31, left) but during the third day after hatching from the egg there is a change which, according to Planta,[6] one of the first to investigate the larval food of honey bees, includes the addition of pollen and honey. More recent investigators, however, are less certain as to the exact nature of this dietary change, for analyses by Köhler,[7] Langer,[8] and others tend to show that larval food does not have any fixed composition but that it is variable within certain limits. Haydak,[9] whose recent investigations support the latter view, is of the opinion that the production of either a queen or a worker is due not to a change in the character of the food itself, but rather to the amount of essential nutrients consumed by queen and worker larvae, respectively. He cites the work of various other researchers in support of this conclusion, and refers to Lineburg's[10] findings that up to about the third day, all female larvae are in the period of so-called mass feeding, always with more food available than can be consumed; that this mode of feeding is continued throughout the entire growth period of queen larvae; but that, after the first 3 days, larvae in worker cells are fed only at intervals. Thus, while queen larvae constantly have access to more food than they can use, worker larvae de-

[5]*See*: 1936. *Gleanings in Bee Culture* **64**:602-603.

[6]Planta, A. von. 1888. Ueber den Futtersaft der Bienen. *Ztschr. Physiol. Chem.* **12**:327-354. Also: 1889. **13**:552-561.

[7]Köhler, A. 1922. Untersuchungen über den Futtersaft der Bienen. *Verhandel. deutsche Zool. Gesellschaft* **27**:105-107.

[8]Langer, J. 1929. Der Futtersaft, die Kost des Bienenkindes. *Bienen Vater* **61**:25-30, 45-48.

[9]Haydak, Mykola H. 1943. Larval food and the development of castes in the honeybee. *Jour. Econ. Ent.* **36**:778-792.

[10]Lineburg, Bruce. 1924. The feeding of honeybee larvae. *U.S.D.A. Bull.* **1222**:25-37.

velop under conditions of partial starvation and are, therefore, undernourished.

As a direct consequence of such underfeeding and in keeping with the well-known effects of undernourishment on numerous other forms of animal life, sexual development is retarded and repressed. The endocrine function of the ovaries, therefore, is interfered with to such an extent that the hormone, or hormones, secreted are insufficient to bring about the development of the anatomical and physiological characters that conform to the normal pattern for a queen bee, and the resulting individual is what we call a worker.

On the assumption that workers are essentially undernourished and underdeveloped queens, Haydak attempted to rear adults from larvae taken from sealed* queen cells and kept without food in an incubator having a constant temperature of 33° C. and relative humidity of 75 per cent. Most of the larvae so treated died in an advanced pupal stage in which some showed characters intermediate between those of queen and worker, but seven definitely possessed the head, mandibles, and sting of a worker. Of the nine that emerged as adults, eight were normal queens, while the ninth resembled a worker, having a typical worker's head and mandibles, and a straight sting.

The average initial weight of such larvae as developed into queens was 14 per cent greater than that for larvae which developed into workerlike individuals. Since the weight of a larva may be taken as a good index of its age, it seems reasonable to assume that the larvae that developed into queens, in spite of the starvation treatment, were the older ones in which the sex organs probably were already well developed when these larvae were deprived of food; whereas, those that developed into workerlike insects were not only smaller but also younger and developed to a lesser degree sexually, so that in them there was greater opportunity for the effects of undernourishment to become operative. Had it been feasible to rear adults from still younger larvae, it seems probable that a greater proportion of workerlike individuals would have resulted.

Partial starvation (from about the third day) of the female larvae that are reared in worker cells may well be an important factor, if not the principal one, involved in the differential growth of workers and queens from identical eggs.

Regardless of the fundamental causes of divergent development, any female larva not more than 2 days old undoubtedly is a potential queen and can become a worker only if the necessary change in treatment is made by the nurse bees at the proper time.

The differential effects† produced on queen and worker larvae, respectively, by the peculiar treatment accorded to each, are so wonderful

*Some were still in process of being sealed.

†Consult Chapter XIX, "The Anatomy of the Honey Bee," for illustrations of anatomical differences.

that they were at first rejected as idle whims by those who had neither been eyewitnesses to them nor acquainted with the opportunities enjoyed by others for accurate observation. The most important of these effects we shall briefly enumerate.

1. The manner in which the larva designed for a worker is treated causes it to require almost half again as long to arrive at maturity as if it had been reared a queen.
2. The organs of reproduction are developed more fully in the queen so that she can perform the primary function of a mother, but the brood-food glands possessed by workers, which enable them to perform the complementary maternal function of wet nurses, are not functional in the queen.
3. In size, shape, color, and structure, queens and workers differ greatly. The lower jaws of the queen are shorter, her head is rounder, she possesses no wax glands, her hind legs have neither brushes nor baskets for collecting pollen, and her sting is curved, instead of straight, and is one-third longer than that of a worker.
4. Their instincts are exceedingly divergent. Reared as a worker, the female will thrust out her sting at the least provocation; whereas, reared as a queen, she may be pulled limb from limb without attempting to sting. Reared as a worker, the female treats a queen with the greatest consideration; but reared as a queen, she will, if brought into contact with another queen, seek to destroy her as a rival. As a worker, she frequently leaves the hive either for labor or for exercise; as a queen, she never leaves after egg laying is once begun except to accompany a swarm.
5. The term of life is materially altered. Reared as a worker, the female honey bee lives not more than a few months at the most; as a queen, she may live several years.

## Duration of Development

The eggs hatch in about 3 days after they are laid. The larva which is intended to develop into a queen spends 5½ days in the larval state (Fig. 15, right), and 7½ days in its transformation through the pupal (Fig. 14) to the adult stage. These periods are not absolutely fixed, being of shorter or longer duration according to the warmth of the hive and the care given by the bees, so that the time elapsing between the laying of the egg and the emergence of the young queen may be anywhere from 15 to 16 days. During hot weather young queens commonly emerge at the end of the fifteenth or near the beginning of the sixteenth day.

## Royal Succession

Earlier in this discussion, it was stated that a colony suddenly left queenless usually has at its command the requisites for producing a young queen, and now that we have an understanding of the principal facts

concerned with the origin of both queens and workers from identical eggs, certain important implications of the former statement follow as a matter of course. Any normal colony having either "female eggs," or larvae therefrom that are less than 3 days old, possesses the requisites for the rearing of young queens; so that, except during the inactive and relatively short broodless period of winter, no normal colony is apt to lack a stock of potential queen material, even though the loss of the mother comes without warning. If we assume that the old queen did some laying in worker cells on the last day of her presence, the bees will have at their disposal a period of nearly a week during which to select cell sites and begin the process of producing queens from individuals which otherwise would have become workers.

Discovery that a queen can be reared from a "worker egg" has for many years been attributed to Schirach.[11] According to Fraser,[12] however, Nickel Jacob, nearly 2 centuries earlier, had instructed his readers to supply queenless colonies with pieces of comb containing very young brood, in order to enable them to rear new queens for themselves. It is evident, therefore, that Jacob knew at least the practical application of the discovery later made independently by Schirach.

A colony having neither "female eggs" nor young female larvae, when its queen disappears, has indeed slight possibility of redressing its tragic loss unless the necessary eggs or larvae are supplied by the beekeeper from some other colony. Various instances have been reported in which a hopelessly queenless colony had succeeded in rearing a queen for itself, presumably from an egg or young female larva "borrowed" by a worker from a neighboring hive. But recent investigations (see "Parthenogenetic Females" in this chapter) suggest the more plausible explanation that such queens probably have arisen by parthenogenetic development from the eggs of laying workers.

### Emergency Cells

Queen cells built under emergency conditions involving sudden loss of the queen, of necessity are of the postconstructed type (Fig. 15), which is to say that the cell is built over and around an egg or, more commonly, around a young larva already residing in the worker cell when selected for rearing as a queen. This is in distinction to preconstructed cells (Fig. 16), which are originally designed and especially constructed for the occupancy of royalty. When such a cell has been brought to the cell-cup stage, in which it resembles an acorn cup, it is ready for occupancy, and construction is resumed only after an egg has been deposited therein. Preconstructed cells usually predominate when a

---

[11] Schirach. 1761. *The New Natural and Artificial Multiplication of Bees.* (Trans. title.) Bautzen.

[12] Fraser, H. M. 1947. Nickel Jacob. *In* Proceedings, Annual Report and Accounts for the Year 1946, Central Association of the British Bee-Keepers' Association. pp. 23-30.

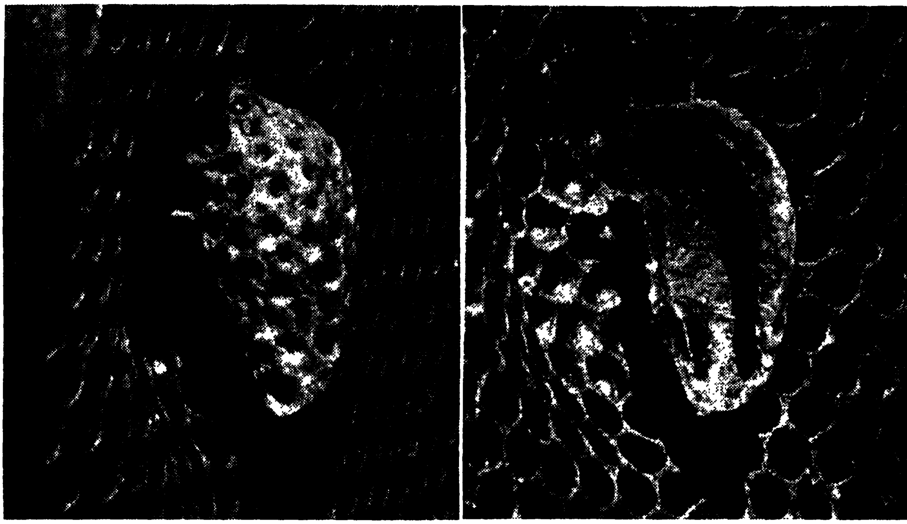


FIGURE 16. A preconstructed queen cell. Left, exterior. Right, interior showing that the cell cavity does not connect with any cell of the comb proper. (*Photo by O. W. Park*)

colony prepares for either supersedure or swarming. They commonly have a thick, bulbous base which is attached to the comb by a shank of wax, so that the cell hangs about perpendicularly and well out from the surface of the comb; whereas postconstructed cells, owing to the nature of their origin and construction, have their bases closely and broadly joined to the comb surface because the cavity always extends to the midrib.

When a larva in a worker cell has been selected for rearing as a queen, the walls of the chosen cell, sometimes but not always, are cut back part way to the midrib before being expanded into the somewhat bulbous base of a queen cell. In the meantime the cell is being stocked with the usual food of young queens, in such abundance that the royal larva soon is floated out of its original narrow confines and into the base of the queen cell proper—a novel means of transportation, to be sure. Assuming that the workers during hot weather had selected a 3-day-old larva, the individual was already 6 days from the laying of the egg; so by the tenth day after the initiation of emergency measures, the colony could be in possession of a new queen. If a younger larva or an egg is used, this period will be accordingly longer.

Queens produced from larvae not more than 2 days old do not differ in anatomical characters from those reared from eggs, and the use of such queens over a period of many years has failed to reveal any shortcoming not found in other queens. The critical age beyond which it is not possible for a female larva to become a queen has been determined[13] as about 3½ days.

[13]Zander, Enoch and Franz Becker. 1925. Die Ausbildung des Geschlechts bei der Honigbiene, II. *Erlanger Jahrbuch für Bienenkunde* 3:161-246.

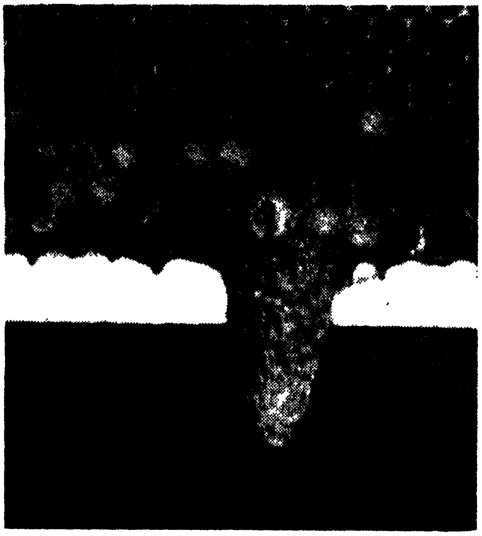


FIGURE 17. A preconstructed queen cell built under the supersedure impulse. Supersedure cells tend to be large and are lavishly supplied with royal jelly. About natural size. (*Photo by O. W. Park*)

FIGURE 18. Under the swarm impulse, numerous queen cells are constructed. Usually one or two are started each day at regular intervals over a period of a week or more. Natural size. (*Photo by O. W. Park*)

There is no question but that, in many instances, queens of a sort are produced from larvae 3 or even 3½ days old when selected for development as a queen. There is, however, a very pertinent question whether such queens are as satisfactory in every respect as are those from larvae selected and cared for as queens beginning not later than on the second day of larval life. Regardless of whether the change in the diet of worker larvae is one of quality or quantity or both, a highly important change of some kind does occur soon after the end of the second day. At three and one-half days of age, then, a larva in a worker cell is presumed to have dieted on worker-larva fare for nearly 1½ days, or a third of the 4-day period that follows the change in food for one destined to become a worker. It is difficult, therefore, to believe that such an individual could possibly develop into a first-rate queen, even though cradled in a queen cell and fed exclusively on royal jelly for the remainder of its larval existence. Serious doubts concerning the desirability of queens reared from larvae over 2 days old appear to be well founded.

### SUPERSEDURE AND SWARMING

Queen supersedure is Nature's provision for replacing a failing queen, thereby making it possible for the colony to perpetuate itself indefinitely without increasing the number of colonies. The term supersedure sometimes has been used to include the rearing of queens under emergency conditions, but as here employed its application is restricted to those cases in which a queenright colony rears a daughter queen to assist or

replace an old or failing mother. In such instances the workers seldom build more than two or three cells, sometimes only one. Supersedure cells may be either pre- or postconstructed, or both types may be represented. There is, however, a widespread opinion that supersedure cells usually are of the preconstructed type. According to Doolittle,[14] supersedure cells (Fig. 17) tend to be large and are lavishly supplied with royal jelly. He expressed as his well-considered opinion that queens produced under the supersedure impulse cannot be surpassed for quality.

As a result of supersedure, exceptions frequently arise to the general rule that two queens do not inhabit the same hive. No animosity appears to exist between mother and daughter in such cases, and it is not uncommon for the old queen to continue to lay for a time after the young one has begun. Usually the old queen disappears within a few weeks but occasionally one remains for months.

Numerous instances could be related in which two queens have been observed at their laying in the same colony—one the aged mother and the other her supersedure daughter. And, because cases of this kind are not so rare as most beekeepers suppose, queens frequently are lost needlessly through attempts at introduction, after having removed only one of the two queens, on the assumption that only one was present. Inasmuch as successful introduction under such circumstances is a rarity, the purchaser of an improved strain of bees—unless he is an exceptionally close observer—is apt to accuse the seller of cheating him. Instances of this kind make the merchandising of queens most disagreeable.

Nature's provision for the reproduction of colonies, as distinguished from reproduction of the individuals that make up a colony, is known as swarming. It involves the multiplication of colonies through division, together with provisions for the production of additional queens. Under the swarming impulse, numerous queen cells are constructed (Fig. 18). As a rule, one or two are started each day, or at irregular intervals, over a period of a week or more. Swarm cells may be either pre- or postconstructed.

Such is a queen's instinctive reaction toward one of her own kind that some have thought it improbable that she should be entrusted with even the initiatory steps for securing a successor, but such is not necessarily the case, for queens as a rule pay little or no attention to the presence of unsealed queen cells. Furthermore, instances in which a queen has been observed in the act of laying in a queen-cell cup, although rare, are not unknown. Among those who have reported such observations are Huber[15] and Doolittle,[16] while the finding of an egg, characteristically attached, in a cell cup is a commonplace experience for any beekeeper.

[14]Doolittle, G. M. 1909. *Scientific Queen Rearing*. pp. 18-20. Chicago, Ill. George W. York & Co.

[15]Huber, Francis. 1926. *New Observations on Bees*. Trans. by Dadant. p. 41. Hamilton, Ill. American Bee Journal.

[16]Doolittle, G. M. 1893. Queens laying in queen cells. *Gleanings in Bee Culture* 21:556.

Pritchard[17] has said that workers often transfer eggs to queen-cell cups and that they fasten them there in their characteristic position. His evidence is wholly circumstantial, however, so it seems highly probable that such eggs could have been deposited by laying workers (see "Parthenogenetic Females" and "Laying Workers" in this chapter). A number of cases have been reported in which eggs, that were being extruded aimlessly by a caged queen, were picked up, transported, and placed in cells of the comb, but evidently not attached, by workers. In such a case of egg-moving which he observed clearly, Pering[18] specifically states that the eggs did not seem to stick as when deposited by a queen. If, however, workers do make a practice of moving eggs into cell cups, as asserted by Pritchard, preconstructed cells logically should occur now and then in colonies that have but recently become queenless; whereas, according to Dr. Miller[19] and others, only postconstructed cells are found.

When preconstructed cells are present, as they commonly are during preparations for either supersedure or swarming, it would seem to be a reasonable assumption that the queen had taken the initiatory steps for providing a successor. The alert apiarist frequently is able to determine the needs of a colony from the type or types of queen cells present.

Commercial production of queen bees, which now has developed into a specialized and highly important branch of bee culture, is based upon two fundamental facts already mentioned: That a queen can be reared from any egg or young larva (not over 2½ days old) that normally would have produced a worker bee; and that a queenless colony having such eggs or young larvae can be counted on to produce and care for a number of queen cells. When conditions are right, a single colony can be induced to build and care for several dozen cells (Fig. 19) at one time and hundreds during the course of a season. The need for production of queens in large numbers will become apparent in later chapters, while the procedure for rearing queens is outlined in Chapter XXI, "The Production of Queens and Package Bees."

### The Virgin Queen

Within the sealed cell, the head of the developing queen lies near the unattached end of the cell (Fig. 14). When ready to emerge, she bites through the fibrous capping where her mandibles conveniently come into contact with it along its circumference. As the cutting proceeds, she turns herself around in the cell until she has cut almost a complete circle when, from its own weight or from a push from the inside, the hinged lid swings open (Fig. 20) and the virgin emerges.

As the young queen moves about the comb, she takes a sip of honey from an open cell and then shortly proceeds to her first important task—

[17]*See*: 1936. *Gleanings in Bee Culture* 64:474.
[18]Pering, Alfred H. 1933. As to that egg-moving stunt. *Amer. Bee Jour.* 73:352.
[19]Miller, C. C. 1915. Kinds of queen cells. *Amer. Bee Jour.* 55:80-81.

that of disposing of all rivals, either actual or potential. In cases of supersedure, as already noted, mother and daughter may live and work in harmony, but if two queens emerge at about the same time, as sometimes happens, the ensuing battle is to the death.

Queen cells, however, usually are started successively over a period of some days, as has been pointed out already; so rivals, if any, generally are of the potential variety, which may be eliminated without hazard to the life or limb of the virgin emerging from the most mature cell. Disposition of any remaining unhatched cells will depend largely upon the future plans of the colony. If swarming is not intended, the virgin is allowed to proceed with the disposal of her rivals. Examples would include not only cases of emergency queen production and of supersedure, in which no swarming is involved as a rule, but also those cases in which the colony has swarmed just recently but plans to cast no more swarms. In any of these cases, events are apt to follow much the same course as that so vividly described by Huber in the following passage:

> Hardly had ten minutes elapsed after the young queen emerged from her cell, when she began to look for sealed queen-cells. She rushed furiously upon the first that she met, and by dint of hard work made a small opening in the end. We saw her drawing with her mandibles, the silk of the cocoon, which covered the inside. But probably, she did not succeed according to her wishes, for she left the lower end of the cell and went to work on the upper end where she finally made a larger opening. As soon as this was sufficiently large, she turned about to push her abdomen into it. She made several motions in different directions till she succeeded in striking her rival with the deadly sting. Then she left the cell; and the bees which had remained so far perfectly passive began to enlarge the gap which she made, and drew out the corpse of a queen just out of her nymphal shell. During this time, the victorious queen rushed to another queen cell and again made a large opening, but she did not introduce her abdomen into it, this second cell containing only a royal pupa not yet

FIGURE 19. A close view of queen cells reared by commercial methods. About ⅔ natural size. (*Photo by O. W. Park*)

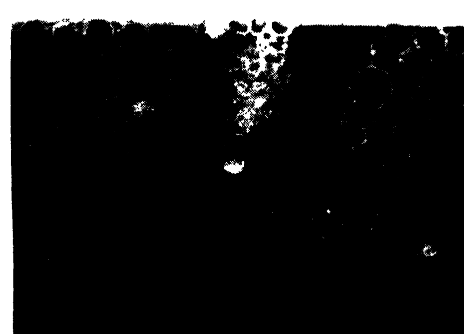


FIGURE 20. A queen cell just vacated. Note hinged lid still attached. About ⅔ natural size. (*Photo by O. W. Park*)

formed. There is some probability that at this stage of development, the nymphs of queens inspire less anger to their rivals; but they do not escape their doom; for, wherever a queen cell has been prematurely opened, the bees throw out its occupant whether worm, nymph or queen. Therefore, as soon as the victorious queen had left this second cell, the workers enlarged the opening and drew out the nymph that it contained. The young queen rushed to a third cell, but she was unable to open it. She worked languidly and seemed tired from her first efforts.—*Nouvelles Observations.*

Huber did not allow this experiment to go on any further, as he wished to use the remainder of the queen cells. Had he left these cells untouched, the bees would have finished the work of destruction. Occasionally the workers undertake the wholesale destruction of such cells without assistance from the virgin, but usually she launches the attack on one or more cells and the workers complete the job, even to the dismantling of unsealed cells which rarely if ever are attacked by the virgin herself. The bodies of the helpless victims sometimes are dragged from their "cradles" entire, especially when nearly mature; but when immature, they are more apt to be removed piecemeal, as the workers often suck the juices from the soft white bodies and remove the tissue bit by bit.

As to the virgin's use of the sting against the inmate of a queen cell, it should be noted that in Huber's account quoted above, this weapon was employed only when dealing with the one and only rival capable of offering any resistance—one that had already completed the transformation from pupa to adult and, therefore, constituted a very real rival that otherwise might have emerged shortly to hotly contest her claim to the "throne."

We have said that the queen bee in no sense governs the colony, and that the workers often circumscribe, if they do not actually determine, certain of her activities. Evidences of the truth of these statements may be found in the following paragraphs.

The facts about to be presented relate to a hive of bees from which the old queen has been removed recently, either by swarming, by accident, or by the apiarist. For the most part, therefore, they are facts associated with the casting of afterswarms (see Chapter IX, "Common Practices in Management"), but they apply equally well to those less-common instances in which a first or prime swarm is accompanied by a virgin queen. In every case, therefore, there will be need for more than one young queen, so the workers assert their authority. They stand guard over the unhatched queen cells and prevent the newly emerged virgin from carrying out her murderous attacks upon them.

Like some human beings who cannot have their own way, she appears as if highly offended when thus repulsed and "hurls vindictives" at her younger sisters, still imprisoned in their respective cells. Her shrill angry note, not unlike the sound of "ze-e-e-ep, ze-e-ep, ze-ep, zeep," uttered in quick succession, usually is called "piping." The definitely prolonged first call is followed by others that are similar but each shorter than the one

before. If held in the closed hand the queen will make a similar noise. To this angry note, one or more of the younger queens, still imprisoned and nursed in their cells by the bees, answer by the somewhat subdued sound, "kooa, kooa," or perhaps more nearly, "quahk, quahk."

The piping call can be given by either virgin or mated queens, while the *"quahking"* is produced only by a young queen within her cell before emergence, so it seems probable that the difference in their "voices" must be due to the confinement of the latter in the cell. This explanation appears to be the more probable since such sounds do not originate from vocal chords. According to Snodgrass,[20] they probably are produced in all cases by the vibration of small plates in the wing bases. A report that a queen whose wings had been entirely clipped off was heard to make this noise, tends to support the explanation given above.

These sounds, so entirely unlike the usual steady hum of the bees, usually may be heard about a week after the old queen has left with the prime swarm, if one will place his ear against the hive, preferably in the evening or early morning when the bees are quiet. Occasionally they are so loud as to be heard at some distance from the hive. Such sounds are almost infallible indications that, weather permitting, a swarm will issue within a day or two, accompanied by the virgin that does the piping.

A newly emerged virgin may be nearly as large as a fertile queen but her size gradually decreases until, after a few days, she is but slightly larger than a worker. At this stage she is most difficult to locate both because of her small size and because she is continually on the move. One can avoid wasting valuable time in a fruitless search for such a queen by placing in the hive a comb containing young larvae just hatched from the egg. If no queen cells are started on this comb within 3 days, one may be assured that a queen is present. Such procedure also enables the colony to rear another queen in case the former one is missing, and it often proves valuable in other ways, as the presence of unsealed brood in a hive is good insurance against various contingencies.

### Impregnation

Although Aristotle[21] related it as the opinion of some that bees breed by copulation, most ancient writers believed that no mating occurs in the honey bee. In 1679, Rusden[22] wrote: "And if the bees do breed without copulation (as almost all writers do agree because it was never yet seen by any man), . . . . it can be no otherwise but by the wind, as Aesop's Babylonian mares (in the fable) conceived by the horses that were in Egypt the same time. Or as a pair of breeches lying upon a bed got the maid with child." Swammerdam[23] believed that the queen is impregnated

---

[20]Snodgrass, R. E. 1925. *Anatomy and Physiology of the Honeybee.* p. 107. New York, N. Y. McGraw-Hill Book Co.

[21]*See*: Googe, Barnaby. 1614. *The Whole Art and Trade of Husbandry.* p. 174. London.

[22]Rusden, Moses. 1679. *A Further Discovery of Bees.* 141 pp. London. (p. 41.)

by the peculiar odor that is given off by drones when confined in a small space. Reaumur,[23] in 1744, thought mating to occur within the hive, while Huish[24] held the opinion that the eggs are fertilized by the drones after being deposited in the cells.

Janscha,[25] the beekeeper royal of Maria Theresa, solved the long-standing mystery and, in 1771, reported his discovery that the mating of queen and drone occurs away from the hive. About 20 years later, Huber (pp. 7-17, Dadant trans.), unaware of Janscha's observations, conducted experiments which proved that mating does not occur within the hive, and that a young queen never lays fertilized eggs (from which queens and workers develop) until about 2 days after she has made a flight in the open, from which she returns bearing the copulatory organs of a drone.

Half a century later Rev. Millette, of Whitemarsh, Pa., published in the *Farmer and Gardener* for Nov., 1859, what appears to be the first eye-witness account of copulation in the honey bee. This observation, together with another which was made by Carey and Otis in the following year, is to be found in an article prepared by Langstroth[26] and published in the first volume of the *American Bee Journal,* 1861. Langstroth and Dadant[27] quote a similar occurrence reported by Alex. Levi in the *Journal Des Fermes,* Paris, 1869.

About a week after birth, the virgin queen goes out to mate. Various earlier authorities have stated that a queen may go out on her marriage flight when only 2 or 3 days old, but most modern authorities agree that anything below 5 days is uncommon. It seems probable that the earlier writers failed to distinguish between nuptial and prenuptial flights.

A prenuptial flight—sometimes more than one—is made in many instances, during which the virgin acquaints herself with landmarks that will enable her to return to her own hive. Such precautions on the part of a young queen are highly necessary, that she may not on her return lose her life by attempting through mistake to enter a strange hive. Such occurrences are not uncommon.

Mating flights, as well as prenuptial flights, usually are taken during the warmest part of the day when drones are on the wing in greatest abundance. Occasionally a queen returns mated within a few minutes, but her absence commonly lasts anywhere from 10 minutes to half an hour and, once in a while, a couple of hours. Up to the present it has been accepted as a fact that a queen bee ordinarily mates but once in her life—at the age of about a week—but numerous reports from authentic sources indicate that many queens mate a second, and some even a third time; but,

---

[23]*See*: Langstroth, L. L. and C. P. Dadant. 1922. *Langstroth on the Hive and the Honey Bee.* 438 pp. Hamilton, Ill. American Bee Journal.

[24]Huish, Robert. 1815. *A Treatise on the Nature, Economy and Practical Management of Bees.* 414 pp. London. (p. 39.)

[25]Janscha, Anton. 1771. *Abhandlung von Schwärmen der Bienen.* 126 pp. Wien.

[26]Langstroth, L. L. 1861. Copulation in the honeybee. *Amer. Bee Jour.* 1:65-66.

[27]*See* p. 43 in source cited in reference No. 23.

in every case, these plural matings occur before she begins to lay. Most queens begin depositing eggs on the second or third day after a successful mating. When once a queen becomes fertile, she never afterwards leaves her hive except when accompanying a swarm.

The age at which a queen mates is subject to considerable variation due to weather and race of bees, but there is evidence to show that, in the Italian race, relatively few matings occur before the sixth or after the tenth day. Latham[28] states that 99 out of 100 of his queens mate on the sixth day if conditions are favorable. Careful studies on the mating and subsequent egg laying of 60 queens were conducted at the Baton Rouge laboratory of the U. S. Division of Bee Culture, in 1937 and 1938, by Oertel[29] whose findings are here summarized: Nonmating flights ranged from 2 to 30 minutes, and mating flights from 5 to 30 minutes. Virgin queens seldom flew more than three times; 18 mated on the first flight, 25 on the second, 9 on the third, and 4 on the fourth. All flights occurred in the afternoon, most of them between 2 and 4 o'clock. Four queens mated twice and two others each made a short flight on the day after mating, but showed no signs of a second mating. Over 50 per cent of all matings took place on the eighth and ninth days. Additional data are summarized below:

| | Earliest | Latest | Most cases on 1 day |
|---|---|---|---|
| | ———— | Day | ———— |
| Seen at entrance | 3d | 11th | 7th |
| Mated | 6th | 13th | 8th & 9th* |
| Laid first eggs (after mating) | 1st | 8th | 3d |

Further important findings on queen matings have been reported by Roberts,[30] also of the Baton Rouge laboratory of the U. S. Division of Bee Culture. Flight data were obtained, during 1939 and 1940, on 110 marked queens that were confined to their hives by means of queen-excluder guards except during periods of observation. When a virgin appeared at the entrance, the guard was removed to allow her to fly, and immediately replaced so that she could not re-enter until she had been examined for signs of mating. Observations were made daily from 12:30 to 5 p.m., and covered the period during which practically all queens and most drones fly.

Of the 110 queens studied, 55 mated twice. One mated twice the same day but usually the two matings occurred on successive days unless unfavorable weather conditions interfered. The average duration of mating flights decreased from 19 minutes in April to 12 minutes in June, presumably due to the increase in drone population, whereas the duration of nonmating flights showed no significant change over the same period.

[28]*See*: Root, A. I. and E. R. 1940. *ABC and XYZ of Bee Culture*. p. 594. Medina, Ohio. A. I. Root Co.

[29]Oertel, E. 1940. Mating flights of queen bees. *Gleanings in Bee Culture* 68:292.

*Equal numbers on eighth and ninth days.

[30]Roberts, William C. 1944. Multiple matings of queen bees proved by progeny and flight tests. *Gleanings in Bee Culture* 72:255-259, 303.

The virgins used were from four breeders, two of which were mother and daughter, while the other two were from unrelated strains. Since the percentage of single and double matings in the progeny from the three strains did not differ significantly, the observed tendency toward plural matings is not a characteristic peculiar to one strain.

Roberts secured additional data on plural matings in 1942 when 35 yellow queens were allowed free flight at mating stations provided with yellow drones. Eight of these mated only with yellow drones, 1 mated only with black drones, while 26 mated not only with yellow drones but also with stray black ones. These results were checked by comparing the color patterns of the worker progeny of these naturally mated queens with the color patterns of the offspring of sister queens artificially inseminated with spermatozoa of drones from the drone-producing colonies at the mating station. Thus it seems evident that plural matings are fully as common as single matings.

Since the mating of the queen and the drone takes place in the air, it is not a common sight, but now and then someone reports having seen a virgin at the head of a cone-shaped group of ardent suitors as she leads them all a merry chase, yielding herself at last to the swiftest flier, in accordance with Nature's law of the survival of the fittest. Observers who have seen a mating at close range, report a sharp snap or explosion as the participants come into bodily contact, then sail through the air for a brief moment and, together, fall to earth before the queen breaks away from her dying spouse, to rise and disappear in the direction of her hive. The crumpled body of the drone remains where it has fallen. If we are near the hive when a queen returns from her hymeneal excursion, we may be assured of her success by the presence of a bit of white tissue protruding from the tip of her abdomen—a token, alike, of matrimony and of widowhood.

But what of the explosion that was heard? Did it have any connection with the fate of the unfortunate bridegroom? Presently we shall see. Up to the very moment of copulation, the male generative organs, folded wrong side out, had occupied an internal position near the tip of his abdomen. Ages ago when Nature found herself confronted with the difficulty of making these deeply hidden organs available when required for procreation, she solved her problem in a singular way. After removing a rubber glove from your hand, did you ever try to turn the fingers right side out again by blowing vigorously into the glove? As pressure develops within, the fingers pop out all of a sudden and assume their righted position with a decided report. The eversion of the genitalia of the drone is brought about in much the same manner. These organs, entirely lacking in muscles, are thus forcefully everted by the contraction of the abdominal walls and the resulting pressure of the blood and surrounding tissues.

The mechanism which sets off this explosive reaction must be very delicately balanced for its equilibrium is easily upset by subjecting the drone

either to decapitation or to slight pressure on the abdomen.* In either case he bursts open something like a kernel of popcorn and dies forthwith, just as in mating. It appears, therefore, that the disruption produced within his own body must be the real and sole cause of the certain tragedy awaiting every bridegroom in beedom. A cruel fate, perhaps, but in complete harmony with Nature's decree that nothing useless shall long survive. And can you imagine anything more useless than a drone bee utterly incapable of performing the only function for which he was created?

Since a queen never has been known to mate after once beginning to lay, it is essential that she acquire, prior to that time, a supply of spermatozoa sufficient to last her a lifetime. Within her body is a sperm reservoir known as the spermatheca, capable of holding the million or more spermatozoa required to fertilize hundreds of thousands of eggs. It has been provided that the genitalia of the drone become so firmly lodged in the genital orifice of the queen that they remain with her when she breaks away from her lifeless mate, to return home bearing them in token of her new estate. Later the shriveled remains of these organs are removed either by the queen or by the workers, but not before ample time has elapsed for the absorption of all the spermatozoa into the genital tract of the queen. A period of several hours is required for all of the spermatozoa to make their way into the spermatheca, where they are to remain to be released as needed to fertilize her eggs as she lays them.

## Egg Laying

The queen begins laying on the second or third day after impregnation. She is seldom treated with much attention by the bees until after she has begun to replenish the cells with eggs (Fig. 21); although if previously deprived of her, they show by their peculiar behavior that they fully appreciated her importance to their welfare.

The extraordinary fertility of the queen has already been noticed. The process of laying has been well described by the Rev. W. Dunbar, a Scotch apiarist:

> When the queen is about to lay, she puts her head into a cell and remains in that position for a second or two, to ascertain its fitness for the deposit she is about to make. She then withdraws her head, and curving her body downwards, inserts the lower part of it into the cell; in a few seconds she turns half round upon herself and withdraws, leaving an egg behind her.—(Langstroth, 1st ed. p. 45.)

In winter or early spring, she lays first near the middle of the cluster, and continues to deposit in cells adjacent to those already occupied, in an ever-increasing, circular or elliptical area. In the meantime she does

*Purchas reports that Aldovondrus (1552-1605) knew that ejaculation can be produced in the drone by gentle pressure on the abdomen. He states also that Virgil (first century B. C.) and others have discussed at length how to effect this reaction. *See*: Purchas, Samuel. 1657. 387 pp. London. (p. 37).

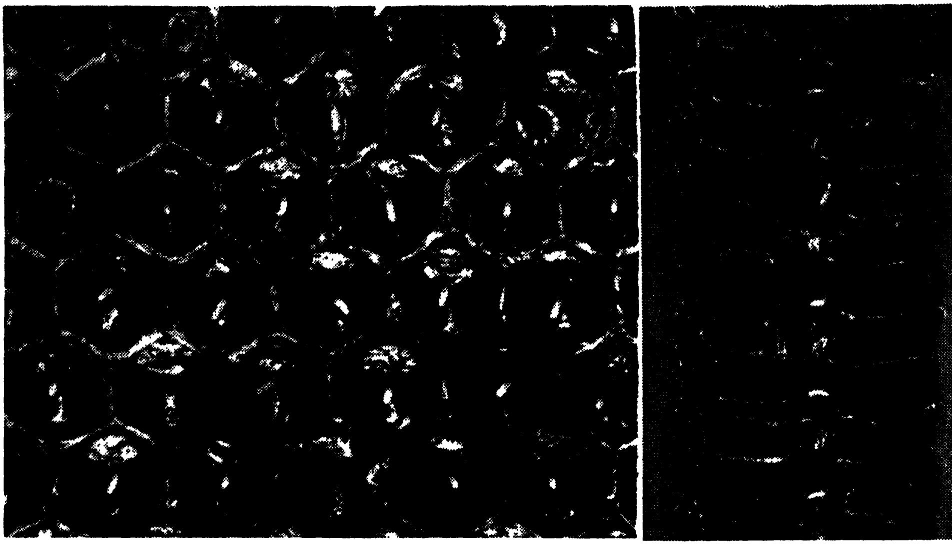


FIGURE 21. At left, a good queen deposits her eggs methodically, one egg to the cell. Enlarged 2½×. At right, vertical section through comb shown at left. Slightly enlarged. (*Photos by O. W. Park*)

not neglect the cells on the adjacent comb surface but supplies them with eggs in a similar manner. And if conditions permit her to pass to the opposite sides of these combs without leaving the cluster, she will continue her methodical laying in contiguous combs until most of the available cells within the warmed space have been occupied.

Queens lay more or less according to: (1) the season, (2) the number of bees that keep up the heat of the brood nest, and (3) the quantity of food which they eat. When bees harvest honey or pollen, or when these necessaries are provided artificially by the apiarist, they feed the queen oftener than they would otherwise; hence her laying increases in spring and decreases in summer or fall. It is certain that when the weather is uncongenial or the colony too feeble to maintain sufficient heat, fewer eggs are matured, just as the number of eggs laid by a hen is diminished by unfavorable circumstances.

A broodless period at some time of the year, varying from a few weeks to a few months, occurs almost universally. In temperate and cold climates this broodless period begins at the approach of cold weather but ends long before the return of warm weather, whereas in hot climates the broodless period is said to occur at the hottest time of the year. Causes of resumption of brood rearing are not well understood but it is generally accepted that in temperate and cold climates, a strong colony with ample stores of pollen, as well as of honey, will resume brood rearing well in advance of weaker ones.

Queens differ much as to the degree of their fertility. Those are best which deposit their eggs with uniform regularity, leaving no cells unsupplied—as the

brood hatches at the same time on the same range of comb, which can be again supplied; the queen thus losing no time in searching for empty cells.—(Dzierzon.)

To test the difference in fecundity of queens, De Layens, while transferring bees in mid-April, counted the eggs dropped on a black cloth in 40 minutes by the queens of four different colonies. The poorest queen dropped but one egg; the second, 12; the third, 18; and the fourth, 20. On the fifteenth of July, the colony of the first queen was very poor, that of the second was of average strength, and both of the others were very strong.

The laying of the queen bee ordinarily diminishes by the end of the first or second year. An old queen sometimes ceases to lay worker eggs. As the supply of spermatozoa in her spermatheca becomes exhausted, the eggs are no longer impregnated and produce only drones, even though they may be laid in worker cells. Such a queen is then known as a drone layer.

The queen bee usually dies of old age in her third or fourth year, although she has been known to live as long as 7 years. Under modern conditions of commercial honey production, however, the usefulness of the average queen does not extend beyond the second year, often not beyond the first.

## Parthenogenesis

Formerly it was believed that no egg could develop without being fertilized, but we now know that such development does occur. While in general it is true that unfertilized eggs do not develop, still the instances in which development does occur are not so rare as most persons presume. In fact this type of reproduction, known as *parthenogenesis,* is a normal phenomenon in numerous branches of the animal kingdom, including crustaceans, rotifers, certain parasitic flatworms, and not a few insects. Parthenogenesis is particularly common among insects of the order Hymenoptera, to which belong the ants, wasps, and bees.

Parthenogenetic development in general is not restricted to one sex. In aphids and certain crustaceans, both sexes may result; in some grasshoppers and certain moths, females only are produced; while in most hymenopterous insects, including the honey bee, unfertilized eggs usually give rise to males only, but occasionally to females. Fertilized eggs have never been known to produce male bees.

Haeckel[31] asserts that Aristotle, who lived more than 300 years B.C., discovered parthenogenesis in honey bees. Of Aristotle he says: "He knew also that embryos come from the eggs of the bee even when they have not been fertilized." Bonnet described the parthenogenetic development of

[31]Haeckel, Ernest. 1905. *The Evolution of Man.* McCabe translation. p. 22. New York, N. Y.

aphids (plant lice) in 1745, and just a century later Dzierzon[32] set forth his theory that the drone of the honey bee arises from an unfertilized egg.

### Dzierzon's Theory

The essence of Dzierzon's theory as originally published is that in honey bees, males (drones) arise from unfertilized eggs while females (workers and queens) arise from fertilized eggs.

Apparently a queen is able to lay either fertilized or unfertilized eggs "at pleasure" as stated by Dzierzon, for with rare exceptions she puts fertilized eggs into the smaller, or worker-size cells, and unfertilized into the larger, or drone cells. And although a queen cell is still larger than a drone cell, when she lays in one, she deposits a fertilized egg. Thus in the honey bee, an egg that receives a sperm, develops into a female which may be either a worker or a queen, depending upon the subsequent treatment given by the nurse bees. The drone or male bee, as already stated, develops from an egg that receives no sperm.

The mechanism which enables the queen to lay fertilized or unfertilized eggs "at pleasure" consists essentially of a spermatheca and a sperm pump.* The spermatheca is a small globular sack connected with the vagina by a small duct which serves first as entrance and later as exit for the spermatozoa. The spermathecal duct is constructed in such a way that part of it forms a sperm pump for the discharge of spermatozoa. By means of this mechanism the queen is able either to withhold or discharge a small number of spermatozoa into the vagina where they come into contact with the egg as it passes on its way to the exterior. One or more spermatozoa enter the egg through the micropyle, a small opening for that purpose near the "head" end of the egg.

Evidences that may be found in the apiary in support of the Dzierzon theory as now modified, are:

1. Unimpregnated queens rarely lay, but if they do, their eggs produce drones almost exclusively.
2. Fertile queens sometimes exhaust their supply of spermatozoa, and the eggs they lay thereafter produce drones almost exclusively.
3. Eggs laid by workers that develop the ability to lay (see "Laying Workers" in this chapter), seldom produce anything but drones, but in some races, at least, they occasionally produce workers and queens as well as drones.

Dzierzon's theory has not been accepted without vigorous protest, but after a full century during which it has been subjected to intensive and extensive investigation by many of the world's most capable biologists, it stands amply confirmed in its essentials, and today is all but universally accepted.

---

[32]Dzierzon, Johannes. 1845. (On the development of bees.) *Eichstädt Bienenzeitung* **1**:113.

*For more details on this mechanism, see Chapter XIX, "The Anatomy of the Honey Bee."

### Parthenogenetic Females

Dzierzon, however, was not wholly correct in his belief that unfertilized eggs never produce anything but drones. During the past fifty-odd years, there has accumulated considerable evidence which shows beyond any reasonable doubt that in certain wasps, as well as in some races of honey bees, unfertilized eggs occasionally produce females.

The first evidence of this kind, according to Anderson,[33] was published in 1892, by Hewitt,[34] of Sheffield, England, who discovered that "Punic workers have the power to raise both queens and drones from themselves." As an example of their ability to produce queens in this way, he gave the following instance: "In one case, a number of Punic workers entered a stock of queenless Carniolans and reared a queen from the eggs they laid." (This queen was deposited in the British Museum in 1892.) His experiments with various races led him to state that "the instinct seems perfect in the Punic bees; only partly so in Syrians, and quite absent in our native bees."

In 1912, Onions[35] reported finding parthenogenetic workers and queens as well as drones in the Cape bee of South Africa, and, in 1943, Mackensen[36] reported the trait in three American-bred strains of European bees.

It should be remembered that Dzierzon was familiar with European races only and that, up to the present, it has been generally believed that European races do not share the ability to produce females parthenogenetically. The question as to the validity of this belief can be answered, if at all, only after further investigations for, as Mackensen points out, it is not at all certain that the strains he tested were purely of European lineage. Various African and Asiatic races, including both Punics and Syrians, were introduced into the United States with more or less success many years ago, and without doubt they mixed with the common bees of this country. In fact the well-known golden bee developed in America is widely believed to be a mixture of either Cyprian or Syrian and Italian races. Since all three of the strains tested by Mackensen had been bred in this country for some years, it is entirely possible that they may have acquired some African or Asiatic blood. At any rate it seems certain that the occurrence of parthenogenetic females in some strains of American-bred bees has been demonstrated, and that on this basis the unexpected appearance of a queen in a colony, considered to be hopelessly queenless, can now be satisfactorily explained.

---

[33]Anderson, John. 1918. Laying workers which produce female offspring. *Amer. Bee Jour.* **58**:192.

[34]Hallamshire Beekeeper (John Hewitt). 1892. Fertile workers—their utility. *Jour. Hort. London* **25**(3):134.

[35]Onions, G. W. 1912. South African "fertile-worker bees." *Agr. Jour. Union S. Africa* **3**:720-728.

[36]Mackensen, Otto. 1943. The occurrence of parthenogenetic females in some strains of honeybees. *Jour. Econ. Ent.* **36**:465-467.

### Practical Applications

It is to be noted that the drone bee has no father and that male inheritance is through alternate generations, for the drone has a grandfather on his mother's side. The drone begets no sons—only daughters. These facts have an important bearing upon the breeding of bees, because the male offspring of a purebred queen are themselves purebred, regardless of the character of the drone with which their mother mated. When, for example, an Italian queen mates with a Carniolan drone, her female progeny will be a cross between the two races. The drones, however, having developed from eggs that received no sperm, will be Italian like their mother.

For breeding purposes, the drone progeny of a mismated queen are considered as satisfactory as those from a mother of pure mating. The basis for judging drones for breeding purposes should be the characteristics of their maiden aunts—the worker sisters of the drone's mother.

For information on the origin of sex cells and the means by which sex is determined in the honey bee, refer to Chapter XIX, "The Anatomy of the Honey Bee." For further information on parthenogenesis, turn to the topic, "Laying Workers," in this chapter, and for exhaustive studies, see Phillips[37] and Nachtsheim.[38]

## The Drone

The drones are the male bees (Fig. 6a and 22). They are much larger and stouter than either the queen or workers (Fig. 6b, c), although their bodies are not quite as long as that of the queen. They have no sting with which to defend themselves, and no suitable proboscis for gathering nectar from the flowers, no baskets on their hind legs for holding pollen, and no glands on their abdomens for secreting wax. They are, therefore, physically disqualified* for the ordinary work of the hive. Their proper office is to impregnate the young queens, a task which they are unable to perform until about 10 days old.

Drones begin to make their appearance in April or May in the North, earlier or later according to the latitude, the forwardness of the season, and the strength of the colony. They go out of the hive only at midday when the weather is warm.

The number of drones in a colony often is very great, amounting to hundreds and sometimes to thousands. As one or two will impregnate a queen for life, it would seem that only a few should be reared. But as matings always take place in the air and young queens necessarily must

[37]Phillips, E. F. 1903. A review of parthenogenesis. *Proc. Amer. Philos. Soc.* **42**:275-345.

[38]Nachtsheim, H. 1913. Cytologische Studien über die Geschlechtsbestimmung bei der Honigbiene (*Apis mellifica* L.). *Archiv. für Zellforsch.* **11**:169-241.

*For anatomical illustrations and further details, see Chapter XIX, "The Anatomy of the Honey Bee."

FIGURE 22. A side view of a drone, the male bee of the colony. Enlarged about 4X. ("*Honey Bee*," *Encyclopædia Britannica Films Inc.*)

leave the hive, it is very important that they be sure to find a drone without being compelled to make repeated excursions. Being larger than workers and less active on the wing, queens are more exposed to the peril of attack by birds and insects, or to destruction by sudden gusts of wind.

As has been shown, the mating of the queen always takes place in the air. Physiologists say that it cannot be otherwise because the sexual organs of the drone cannot be extruded unless his abdomen is swelled by the filling of all the tracheae with air. This is believed to happen only in swift flight.

Dzierzon supposed that the sound of the queen's wings, when she is in the air, excites the drones, but this is open to question for we have no positive assurance that bees can hear. Evidently their eyes, which, according to Cheshire,[39] are highly developed, help them in the search for the queen, which is their sole occupation when in the field. In the hive, they are never seen to notice her, so that she is not molested even if thousands are members of the same colony. But outside of the hive they readily follow her, led doubtless by the senses of smell and of sight, which are thought to be more perfect than those of the worker, most likely for this single purpose. His ability to keep the queen in sight during the pursuit is no less helpful than swiftness on the wing, although the fleetest drone is more apt than another to fulfil his mission in life. The slow and the

[39]Cheshire, Frank R. 1886. *Bees and Beekeeping*. Vol. 1. pp. 111-119. London.

weak die without heirs; thus survival of the fittest is not an accident, but a provident predetermination.

As already mentioned, the drone perishes in the act of mating, his life snuffed out by the convulsive force required to bring about the extrusion of the copulatory organ. The penis bulb, which carries the sperm mass, becomes so securely lodged in the vaginal pouch that it is severed from the drone and carried away by the queen, as she frees herself from her dead spouse.* The wisdom of this provision of Nature becomes apparent when it is understood that some hours are required for the supply of spermatozoa to complete the migration necessary to reach its destination, the spermatheca.† Were the queen to remain in the air with the drone for so long, great risk of being devoured by birds would be incurred.

Experience has proved that impregnation may be effected not only when there are no drones in the colony of the young queen, but even when there are none in her immediate neighborhood. The fact that copulation takes place in the air and usually at some distance from the hive favors the crossing of stocks, which may be beneficial in many instances. In a large apiary, a few drones in each hive or the number usually found in one would suffice. Under such circumstances bees are not altogether in the same status as a colony living in the forest where it may have no neighbors for miles.

## Population Control

Production of excess drones should be discouraged by the beekeeper. The brood area required for the production of a thousand unproductive drones can produce 15 hundred useful workers. The drone larvae require more food because of their greater size, and the adult drones are regular gluttons. Some colonies, left to their own devices, as in a state of nature, produce so many drones that a great part of the surplus crop is consumed by these voracious "loafers." The importance of preventing the overproduction of drones has been verified by the discovery of Mahan‡ that those leaving the hive have quite a large drop of honey in their honey sacks, while those returning from their pleasure outings have consumed their food and are ready for a new supply.

Because of their prodigious appetites and the comparatively greater volume of their digestive organs, drones commonly void their feces within the hive, while workers void theirs out of doors while in flight. This ex-

*Following up a long-overlooked suggestion made by Maurice Girard in 1878, Laidlaw found evidence that the queen probably frees herself from her mate by cutting through the penis wall with her mandibles, which are admirably fitted for such use. *See*: Laidlaw, Harry H., Jr. 1944. Artificial insemination of the queen bee (*Apis mellifera* L.): Morphological basis and results. *Jour. Morph.* 74(3):429-465.

†Laidlaw (1944) says: "The sperm begin an immediate migration from the oviducts into the spermatheca. The spermatheca is nearly filled 6 to 7 hours after mating. The mucus disappears, possibly by absorption. Eighteen to 24 hours after mating, the oviducts are free, or nearly free, of sperm."

‡P. J. Mahan was one of the first to import Italian queens into this country.

plains why the cells of the combs of colonies which have a large number of drones become dark and thick sooner than others.

"The drone," says quaint old Butler, "is a gross, stingless bee, that spendeth his time in gluttony and idleness. For howsoever he brave it with his round velvet cap, his side gown, his full paunch, and his loud voice, yet is he but an idle companion, living by the sweat of others' brows. He worketh not at all, either at home or abroad, and yet spendeth as much as two laborers; you shall never find his maw without a drop of the purest nectar. In the heat of the day he flieth abroad, aloft and about, and that with no small noise, as though he would do some great act; but it is only for his pleasure, and to get him a stomach, and then returns he presently to his cheer."—*The Feminine Monarchy.* (1609.)

Drone traps, which we are prone to consider a modern invention, have been in use for more than 2,000 years, and the essential principle then employed is still in use today. We learn from Aristotle[40] that some bee-masters of that time excluded the drones from the hive—when taking their accustomed airing—by placing in front of the entrance a grating[41] of wickerwork through which the workers could pass, but the drones because of their greater size could not.

While excess drones may be removed from a colony by means of Alley's queen-and-drone trap,* as improved by Batchelder, it is much better to save the bees the labor and expense of rearing them. This can be done to best advantage through the use of full sheets of worker-size comb foundation in every frame so that the bees will construct but few drone cells. When comb damage involves injury to the midrib, bees usually rebuild with drone cells. Thus over a period of years there is a gradual decrease in the brood-rearing value of a high percentage of combs used in the brood nest.

Culling of brood combs is a profitable procedure which may be carried out to best advantage during spring inspections, when combs contain minimum stores. It is well to replace not only those containing any considerable number of drone cells but also such as have been sufficiently damaged by mice, or otherwise, to offer the bees an opportunity to construct drone cells.

Whereas the apiarist is strongly tempted to use such combs in extracting supers, the practice is to be condemned because many such combs eventually find their way back into the brood nest in spite of the best intentions of the beekeeper. Culled combs rendered into beeswax and turned into worker foundation, instead of returning to plague the beekeeper, will contribute to his success.

Unable to gather nectar from flowers, drones are dependent upon their maiden sisters for sustenance, and, having no sting, they are indeed defenseless beings whom the workers drive from the hive, at the close of

[40]Aristotle. 1910. *Historia Animalium.* Bk. V. Ch. 22. Thompson trans. Oxford.

[41]*See:* Googe, Barnaby. 1614. *The Whole Art and Trade of Husbandry.* p. 167. London.

*The perforated zinc used in drone traps, which we think was invented by Collin (*Guide*, p. 3, Paris, 1865), is so cut that neither queen nor drone, but only the worker bee, can pass through its openings.

the honey harvest, to die of starvation in front of the entrance (Fig. 23). Although instances in which drones are stung to death apparently are rare, to say the least, the worker bees pretend to sting, and in various ways worry them. When sufficiently weakened by starvation, they are easily driven from the hive. If not ejected in this manner, they often are so persecuted and starved that they soon perish within the hive. At such times, they may be found by themselves upon the sides or on the bottom board of the hive. In times of dearth, this treatment extends even to the drone brood which is pulled from the cells and destroyed.

While drones are almost always destroyed whenever forage becomes scarce, queenless colonies often retain them indefinitely. If bees could gather nectar and could swarm throughout the entire year, drones probably would live on to die a natural death. As it is, very little is known concerning their life span.

Thus these individuals, which were raised with devoted attention, are destroyed when there is no longer any occasion for their services; and the food which they would have consumed is conserved for the perpetuation of the colony.

### Undersize Drones

Drones sometimes are raised in worker cells. As a rule this occurs only in a colony headed by a drone-laying queen or in a queenless colony infested with laying workers. Occasionally, however, some drone brood in worker cells appears in a colony having a very prolific queen. Heretofore

Figure 23. This tragedy, recorded by the camera on a frosty fall morning, tells better than words the fate of the drones. (*Photo by G. A. Pauli*)

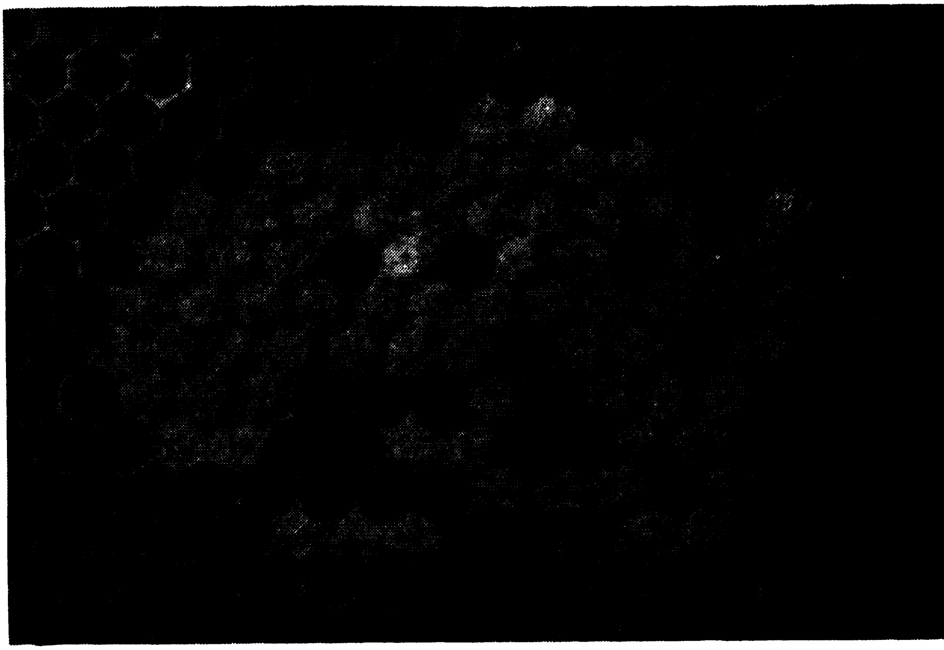


FIGURE 24. Worker brood produced by a queen inseminated with sperm from a small-size drone whose mother was a laying worker. Enlarged about 1½X. (*Photo by O. W. Park*)

such cases sometimes have been explained on the basis of a presumed fatigue of the queen, but another and perhaps more plausible explanation is that this drone brood developed from eggs laid, not by the queen but by fertile workers. Drones reared in worker cells are undersize, as might be expected on account of the restricted quarters in which they grow, but all of their organs are well developed and apparently they are as perfect individuals as full-size drones.

The question has been asked repeatedly as to whether drones produced from laying workers are functional. Two points are involved: (1) Whether such drones are capable of copulating with a queen bee, and (2) whether they produce virile spermatozoa.

It is indeed doubtful if anyone has witnessed a mating between a queen and one of these undersize drones but, aside from the fact that his small size might prove a serious handicap especially if in competition with larger drones, there is no known reason why he should be incapable of copulation.

Information regarding the second point is more definite. In his master's degree thesis, Dr. Millen,[42] now head of the Department of Veterinary Medicine at the Agricultural Institute of Alahabad, India, reported investigations in which he obtained worker brood from two different queens which he inseminated by instrumental means, using sperm from small-

[42]Millen, T. W. 1939. *Comparative studies on the drone progeny of queen bees and laying workers.* Unpublished thesis. Library, Iowa State College. Ames, Iowa.

FIGURE 25. A side view of a worker bee in motion. Enlarged about 4X. (*Photo by O.W. Park*)

size drones known positively to be the progeny of laying workers (Fig. 24). Prior to insemination, these queens and drones had been confined continuously to the respective hives in which they emerged from their cells. Upon being inseminated, the queens were clipped and again confined to their hives by means of perforated zinc. From his experience, Millen concluded that in some instances, at least, the progeny of laying workers are virile. Further evidence of the virility of drones from laying workers has been supplied by Watson and Whitney.[43]

## The Worker

The workers are the smallest inhabitants of the beehive and compose the bulk of the population (Fig. 25). Their numbers decline during the winter and early spring, until even the strongest colonies have fewer than 15,000 workers, while many weak ones will be found to contain but a few hundred. With the return of warm weather, and stimulated by fresh supplies of pollen and nectar, the rearing of workers progresses at an ever-increasing rate until a maximum population is reached in late spring or early summer. During the height of the breeding season, the number of worker bees (Fig. 26) in a colony of good strength commonly exceeds 30,000; and strong colonies may contain two or three times this number.

[43]Watson, Lloyd R. and Rae Whitney. 1945. Drones from laying workers are fertile. *Amer. Bee Jour.* 85:155.

Charles Butler, in his *Feminine Monarchy,* first published in 1609, appears to have been the first to state that workers (and queens) are of the female sex. He was in error, however, in believing that the workers mate with the drones and lay the eggs from which both workers and drones arise. It was nearly 2 centuries later when Huber (pp. 213-221, Dadant trans.) established it as a fact beyond doubt that worker bees are females. In so doing he confirmed not only the claim of Butler but also the opinion of Schirach (see "Royal Succession" in this chapter) who reached that conclusion as a result of his discovery that a queen can be raised from a "worker egg." For a long time worker bees had been considered neuters. Huber points out that even Swammerdam, noted anatomist that he was, held them to be sexless, and that both Reaumur and Maraldi concurred in this opinion.

At Huber's request, Miss Jurine undertook anatomical studies which brought to light ovaries, those female organs which, as Huber puts it, "had escaped the scalpel and the microscope of Swammerdam," doubtless due to faulty technique in preparation of the tissues to be examined. Huber cited Riem as the first to discover that workers sometimes lay eggs, an additional proof that they are females. Still further evidence of the sex

FIGURE 26. Workers compose the bulk of the population. Eight thousand workers and about 20 drones emerged from this comb within a few days after this photograph was taken. (*Photo by O. W. Park*)

FIGURE 27. An egg when deposited by the queen is fastened by the smaller end to the cell base near its center by a mucilaginous secretion, and stands out at right angle to the midrib of the comb. Note prone egg in lowest complete cell on left side of the midrib. Vertical section through the worker cells of a brood comb. Enlarged 4×. (*Photo by O. W. Park*)

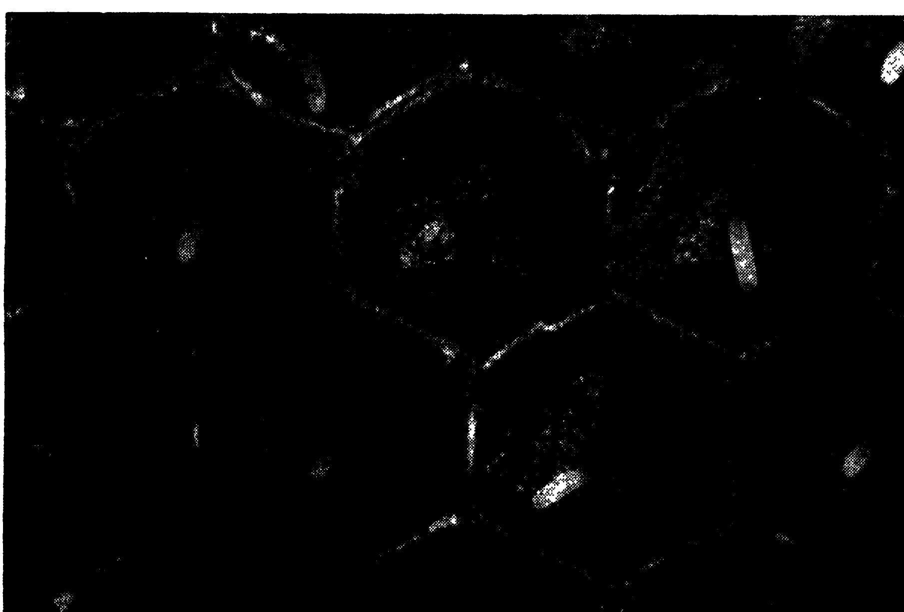


FIGURE 28. Looking into worker cells that contain eggs. Cell walls were shaved down to admit extra light. Enlarged 6×. (*Photo by O. W. Park*)

of worker bees was added half a century later when it was demonstrated by Professor von Siebold and others that workers and queens originate from identical eggs, as asserted by Dzierzon.

## Developmental Stages

Development from the laying of the egg to emergence of the adult worker requires about 21 days, but the period may be slightly shortened in hot weather or lengthened if the immature insect is subjected to low temperatures. Average duration of egg, larval, and pupal stages in the worker are approximately 3, 6, and 12 days, respectively.

The development of the honey-bee embryo within the egg prior to hatching is a subject far beyond the scope of a work of this kind. Those interested are advised to refer to the thorough account of this developmental stage by Nelson.*

Eggs when deposited by the queen are fastened by the smaller end to the cell base by a mucilaginous secretion, and stand out at right angles to the midrib of the comb (Figs. 27, 28). By the time an egg is ready to hatch, its unattached end has descended until the egg lies against the base of the cell (note prone egg in Fig. 27). About 3 days after the egg is laid, a tiny white larva hatches (Fig. 29). Nurse bees, ever on the alert for new arrivals in the colony nursery, immediately surround it with relatively large quantities of royal jelly in which it appears to float (Fig. 31, left). The body of the young larva, resting on one side—either right or left—against the cell base, assumes a crescentlike curve. With growth and development its shape becomes more nearly a circle which gradually takes on the hexagonal outline of its confining boundaries, for the mature larva completely fills the basal end of the cell (Fig. 31, right).

Like other insects, during their growing stage, the honey-bee larva sheds its skin from time to time. This is necessary because the skin, or exoskeleton, of insects is relatively inelastic except for a brief period just after moulting, so increase in size can be effected only at such times. The worker larva thus "lets out its belt" a notch at a time at approximately 24-hour intervals four times in succession, and then not again until 4 days later when the fifth and final larval moult occurs. The insect goes through a sixth moult, however, at the time the pupa attains the adult stage, some hours prior to emergence. The feeding period for a worker larva comes to an end with the sealing of the cell, which usually occurs near the end of the eighth day from the laying of the egg. The larval stage does not, however, end simultaneously with the sealing of the cell.

Studies reported by Bertholf,[44] form the basis for the following account of changes that take place after the cell is sealed. The larva spins its cocoon at the end of the ninth day, and on the tenth stretches out on its

---

**See:* Nelson, James Allen. 1915. *The Embryology of the Honey Bee.* Princeton, N. J. Princeton University Press.

[44]Bertholf, L.M. 1925. The moults of the honeybee. *Jour. Econ. Ent.* **18**:380-384.

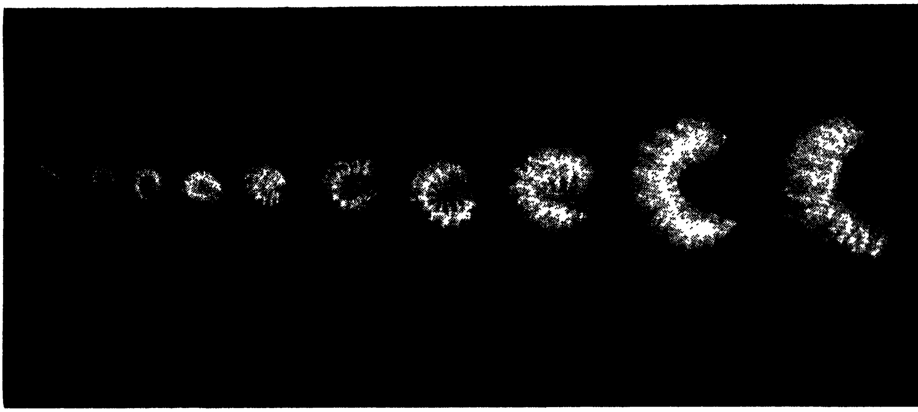


FIGURE 29. Successive stages of development from egg to mature larva. Enlarged slightly.

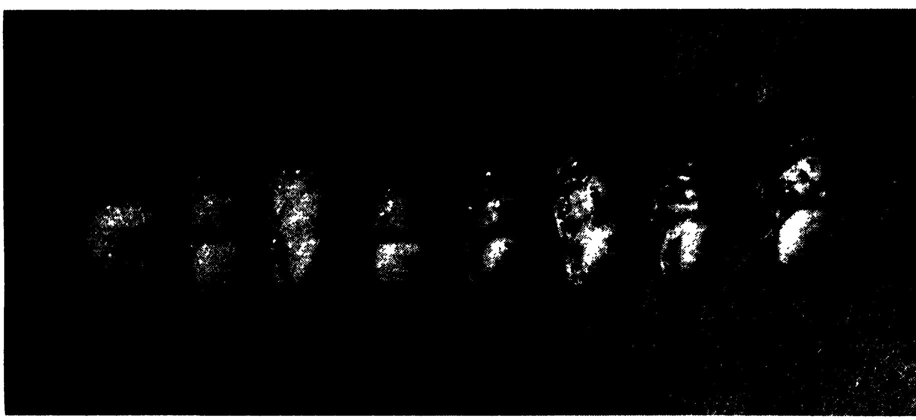


FIGURE 30. Successive stages of development from mature larva to adult bee. About natural size. (*Photos courtesy Division of Bee Culture*)

back with its head toward the mouth of the cell, then becomes quiescent. This marks the beginning of the prepupal stage (Fig. 32, upper). Vital changes already are in progress so that the individual is no longer a true larva although it still looks like one; nor is it as yet a true pupa although, when not dealt with separately, this stage commonly is included as part of the pupal stage. The larva passes gradually and without moulting into this intermediate stage toward the end of which the legs and parts of the head of the developing pupa can be distinguished underneath the old larval skin. About the end of the eleventh day from the laying of the egg, the insect becomes slightly active for a few hours and sheds its fifth and last larval skin, thereby revealing the motionless, uniformly white young pupa. In this stage, the head, thorax, and abdomen constitute distinct body regions, while compound eyes and various appendages are now in evidence (Fig. 32, lower).

Although changes during metamorphosis are described in a number of stages, it is desirable to understand that they do not occur as abrupt transformations but that they proceed gradually from one to another (Fig. 30). At a rate that is imperceptible, the wormlike body of the larva gradually is reconstructed into three distinct body regions, while the larval organs become modified and converted into those necessary for adult life. Eyes, antennae, and mouthparts appear on the head, wings and legs on the thorax, and the abdominal region of the larva acquires adult form. Color changes in general become apparent first on the anterior parts of the body and last on the posterior. Pigmentation shows up first in the compound eyes which, on the thirteenth day, change to pink, then red, purple, and finally to brown by the time of emergence. Upon completion of metamorphosis, marked by the shedding of the pupal skin, the insect again becomes active and, after gnawing through the cell capping, pushes its way out of the cell to emerge as an adult worker (Fig. 33).

SUMMARY OF DEVELOPMENTAL STAGES

| | *Queen* | *Worker* | *Drone* |
|---|---|---|---|
| | | Day | |
| Egg hatches . . . . . . . . . . . . . | 3d | 3d | 3d |
| Cell is capped . . . . . . . . . . . | 8th | 8th | 10th |
| Adult emerges . . . . . . . . . . . . | 16th | 21st | 24th |

## DUTIES OF WORKERS

Worker bees are befittingly named, for they do all the work of hive and field except that under normal circumstances they do not lay eggs.

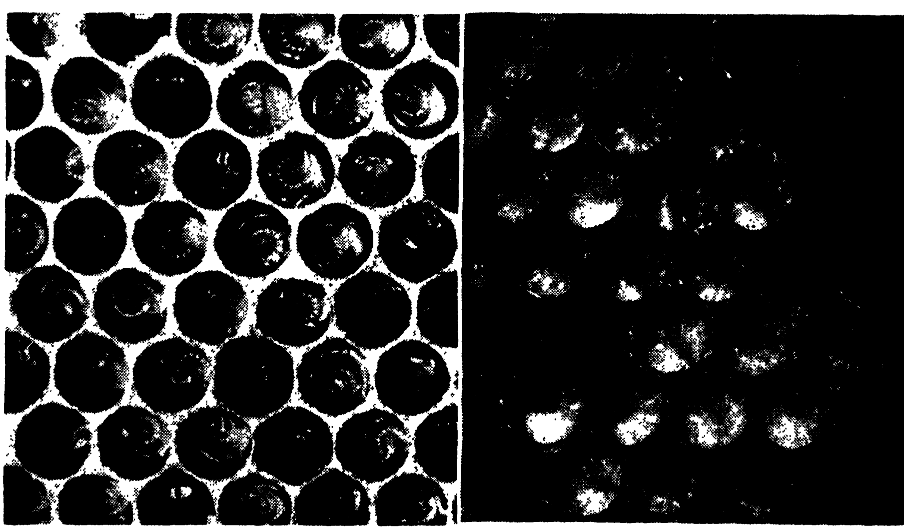


FIGURE 31. At left, worker larvae, 1 to 2 days old, surrounded with relatively large amounts of royal jelly in which they appear to float. At right, worker larvae approximately 4 days old. At this age the larvae completely fill the bottoms of the cells. Enlarged 2 X. (*Photos by O. W. Park*)

FIGURE 32. Vertical section through comb showing cells on only one side of the midrib. *Upper:* Prepupal stage. *Lower:* Pupal stage of worker bee. Enlarged about 4X. (*Photo by O. W. Park*)

FIGURE 33. Young adult worker emerging from the cell in which she developed. Her bedraggled appearance is soon improved by grooming herself. Enlarged 3X. (*Photo by O. W. Park*)

Their functions are varied. The young bees work inside the hive, prepare and distribute the food to the larvae, take care of the queen by brushing her with their tongues, nurse her, maintain the heat of the colony, or renew the air and accelerate the evaporation of excess moisture from the newly stored honey by using their wings for ventilating fans. They clean the hive of dirt or debris, close with propolis the cracks and crevices that might harbor worms or moths or allow heat to escape, and secrete most of the wax that is produced by the colony.

The old bees may, if the occasion demands, do a part of the same work but, as will be explained later, old age renders them unsuited for preparing the food of the queen and of the younger larvae, also less efficient in the secretion of wax. More capable and alert than the young bees, they do the outside work—gather nectar, pollen, and water for the use of the colony, and collect propolis to cement the cracks. Activities of workers and the manner in which their labors are divided are treated more fully in Chapter IV, "Activities of Honey Bees."

Of the numerous ways in which the structure of the worker is particularly adapted for the performance of special tasks, only a few will be mentioned here. Her tongue, which is longer than that of either queen or drone, is well suited for gathering nectar from flowers; her legs are especially adapted for the collection and transportation of pollen; and she alone is provided with glands that secrete the wax from which the combs are constructed. For further details and for anatomical illustrations, consult Chapter XIX, "The Anatomy of the Honey Bee."

A newly emerged worker bee is easily recognized by her apparent smaller size, bedraggled appearance, and weak condition. After a few days she appears considerably larger, the hairs of her body have been carefully groomed, and her appearance is bright and fresh.

The young bee first ventures out of the hive when she is about 8 to 10 days old. Disturbance of the colony, lack of a sufficient number of old bees, or an excess of young ones may cause her to go out sooner. The young bee usually goes out with others of approximately the same age. She first walks about in front of the entrance in a hesitating manner and then takes flight. The first flight of young worker bees is easily remembered when once seen. Their peaceable circling in front of the hive to reconnoiter the location of their home reminds one somewhat of the playing of children in front of a schoolhouse. Their swaying, pleasant flight is easily distinguished from the restless movements of robber bees.

### Laying Workers

Although the workers are females, they possess only rudimentary ovaries (Fig. 34, left) and barely a trace of the seminal reservoir, or spermatheca, so they are incapable of fecundation. In some of them, these rudimentary ovaries contain a few undeveloped eggs and, under abnormal conditions, some become sufficiently developed to enable the worker to lay eggs (Fig. 34, right). It has been the common belief that eggs of laying workers never produce anything but drones; but, as was pointed out in the discussion on parthenogenesis, it is now known that in certain races, at least, they sometimes give rise to workers and queens as well as drones.

Ability to produce queens parthenogenetically from the eggs of laying workers appears to be most common among African races, notably the Punics of North Africa. This faculty gives an important advantage to such races as possess it, for they are enabled thereby to bridge successfully the chasm of hopeless queenlessness and preserve the continuity of the race. The rarity of this ability, if not indeed its total absence in European races of unmixed lineage, is a marked defect which doubtless could be corrected through proper breeding. Those who would breed the ideal bee should give due consideration to this trait.

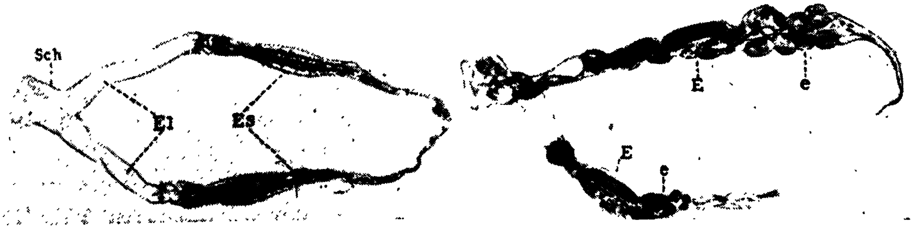



Figure 34. At left, ovaries of a normal worker bee. Sch. vagina; El, oviducts; Es. ovaries. Enlarged about 5½×. At right, ovaries of laying worker. E, fully developed eggs; e, eggs in early stages of development. Enlarged about 4×. (*After Leuenberger*)

FIGURE 35. Bees of a laying-worker colony often attempt in vain to rear queens from the eggs laid by workers. Note four sealed queen cells and characteristic bullet-nose drone cappings on other brood cells. (*Photo by O. W. Park*)

In European races also, the bees of a laying-worker colony, in their extremity often attempt to rear queens from eggs laid by workers (Fig. 35), but their efforts rarely if ever are successful. Once in a while a queen cell of the preconstructed type is encountered in a laying-worker colony, built undoubtedly from a cell cup in which an egg has been laid by a worker. In nearly all cases, however, the cells are of the postconstructed type, built around selected larvae which are copiously supplied with royal jelly. The poor overfed drones thus treated grow for a time but eventually perish in the cell without reaching maturity, except possibly in rare instances in which the individual may turn out to be a female that has developed parthenogenetically, and in that case doubtless would mature into a normal queen, just as in Punics and certain other races. As pointed out previously, the parthenogenetic development of queens under such circumstances adequately accounts for the unexpected appearance of a queen in a colony regarded as hopelessly queenless. Cases of this kind have not been explained satisfactorily heretofore.

The fact that European races frequently make the attempt to rear queens from eggs of workers might be considered as definitely favorable for future development in them of this desirable trait.

Laying workers seldom are observed in races of European origin until a colony has been queenless for some time. According to Dzierzon,[45] "The

[45]Dzierzon, Johannes. 1882. *Dzierzon's Rational Beekeeping*. Trans. by Dieck and Stutterd. p. 24. London.

case of a worker laying eggs when there is a fertile queen in the hive is very rare, yet it sometimes happens like the exceptional occurrences of two fertile queens in one stock at the same time."* Millen working with Italians (see reference No. 42 in this chapter), found that they do not produce fertile workers as long as the colony has eggs or young larvae, or something that the bees regard as a queen. The shortest time in which he was able to induce laying workers was 6 days after removal of a virgin from a swarm, and the longest, 26 days after removal of the queen from a normal colony. Later, working in India, Millen[46] found that *Apis indica* often has laying workers even when brood and queen cells are present, whereas with *Apis mellifera* they were not found until 5 to 13 days after the last queen cell had been removed.

The activating cause of development of egg-laying ability in workers has been the subject of much speculation and some research. Huber (p. 44, Dadant trans.) thought that fertile workers† are reared in close proximity to young queens, and that development of the ovaries occurs only in such workers as receive, through accident or some unknown instinct, small quantities of royal jelly during the larval stage. The Dadants[47] considered it more probable that when the hive has suddenly become queenless the young bees, having no more larvae to nurse, feed each other their milky food which excites egg laying in them as it does in queens. The latter view is supported by the recent studies of Gertrud Hess,[48] who found that the brood-food glands of workers become well developed immediately after the colony becomes queenless and that an increase in the development of the ovaries of numerous workers takes place about a week later. Bees of any age may develop the ability to lay. In several of the laying-worker colonies which Hess studied, she found eggs in the ovaries of more than half of the 100 workers examined from each. In a colony that had been queenless for 3 months, she found 87 per cent of the worker population to be potential layers.

Results of the activities of laying workers are readily detected. Among European races,‡ the telltale appearance of dome-shaped cappings on

*Laying workers in queenright colonies probably are more common than we think due to inability to detect their presence except when seen in the act or determined by dissection.

[46]*See*: 1943. *Bee World* 24:38.

†An extract from Huber's preface will be interesting in this connection. After speaking of his blindness, and praising the extraordinary taste for natural history of his assistant, Burnens, "who was born with the talents of an observer," he goes on to say: "Every one of the facts I now publish, we have seen, over and over again, during the period of eight years, which we have employed in making our observations on bees. It is impossible to form a just idea of the patience and skill with which Burnens has carried out the experiments which I am about to describe. He has often watched some of the working-bees of our hives, which we had reason to think fertile, for the space of twenty-four hours, without distraction . . . and he counted fatigue and pain as nothing compared with the great desire he felt to know the results."

[47]*See*: 1893. *Langstroth on the Hive and the Honeybee.* Revised by Chas. Dadant & Son. Second edition of the revision. p. 74.

[48]*See*: 1942. *Bee World* 23:61-62.

‡The remainder of this discussion on laying workers applies more particularly to European races.

worker-size brood cells is a sure sign that all is not well with the colony. Either the queen has become a drone layer or she has been missing for some time, and laying workers have developed. Fertile workers show a decided preference for large cells and are not much inclined to lay in worker cells when drone cells are available. Queen-cell cups also receive due attention. The eggs of a queen are very regularly laid (Fig. 21) while those of workers are laid without order. The brood of a drone-laying queen, therefore, usually shows considerable compactness and uniformity of age, whereas that of laying workers is scattered promiscuously so that cells containing grown larvae or sealed pupae may stand right by the side of those containing eggs. Furthermore, the eggs laid by a queen, even a drone layer, are attached, one to the cell, near the center of the cell base, while those of fertile workers are not uniformly placed and the number in a cell may run as high as a dozen or more. Although sometimes two or three drone larvae begin development in a single cell as a result of such multiple depositions (Fig. 36), all but one disappear before the cell is sealed. As already mentioned, Millen has demonstrated that small drones reared in worker cells from eggs laid by workers are potent.

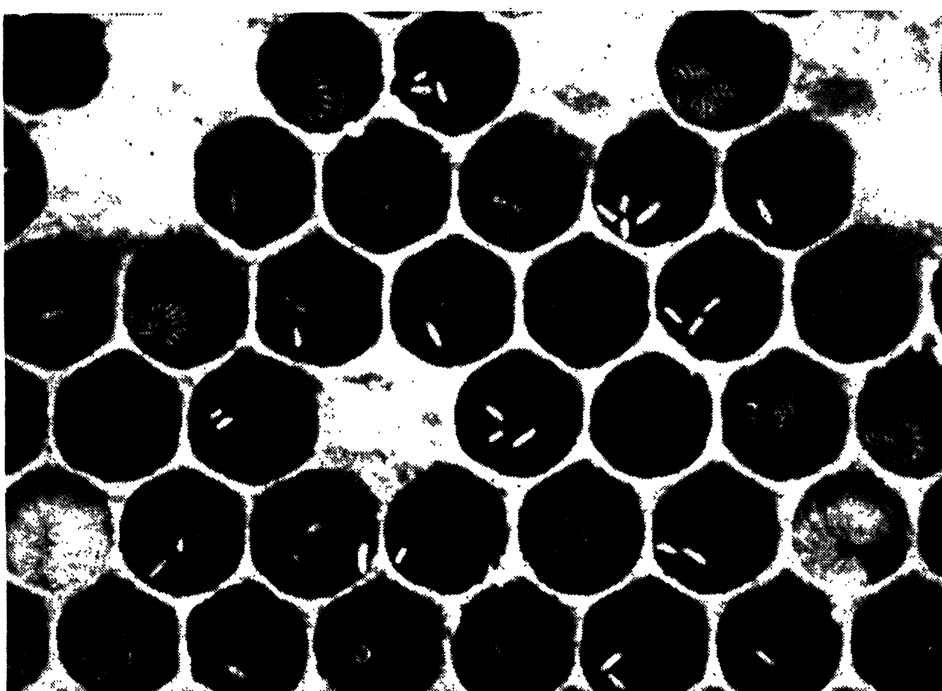


FIGURE 36. Laying-worker brood. Two larvae in one cell may be seen in second cell from left in third row from top, also at extreme right in fourth row. Three larvae are in open cell near right end of top row. A very tiny larva just out of the egg appears in third cell from left in bottom row, near lower left border of cell. Just above this cell an egg has been attached near mouth of cell. Enlarged 3×. (*Photo by O. W. Park*)

Outside of a certain educational value in some instances, a laying-worker colony is an unmitigated nuisance in the apiary. Its presence usually indicates neglect on the part of the beekeeper and its value quickly drops to the vanishing point. Without timely assistance from the apiarist the working force soon dwindles away and the colony perishes. The demise of such a colony often is greatly hastened through its latter stages by depredations of wax-moth larvae (see Chapter XXIII, "Diseases and Enemies of the Honey Bee").

Occasionally, in a laying-worker colony, we have seen a worker surrounded by a circle of attendants and receiving all the attentions normally bestowed upon a queen. This behavior suggests why such a colony seldom can be induced to accept a queen even when one is introduced with the utmost care. Sometimes a laying-worker colony will succeed in raising a queen from young brood which may be given by the apiarist but more often it fails unless some emerging workers are given at the same time. It would appear, therefore, that young bees must be indispensable for the proper nursing of the developing queen.

While it sometimes is possible to restore a laying-worker colony to the normal, queenright condition, it seldom pays to expend the effort. Conditions should determine procedure. If young bees and worker brood are present, the most practical treatment is to unite the colony with one that is normal. In case little or no worker brood is present, shake out the bees in front of neighboring colonies and remove the hive just vacated.

Prompt requeening of all queenless colonies largely eliminates the development of laying workers, so it is well to remember that prevention is better than cure and, in this case, far easier to accomplish.

## Life Span

The life span of worker bees generally is short, but depends very much upon the extent and severity of their labors and their exposure to injurious elements. Those reared in the spring and early part of summer, upon whom fall the heaviest labors, live not more than 35 or 40 days as an average; while those bred at the close of summer and early in autumn, being able to spend a large part of their time inactive, attain a much greater age. It is evident that the bee, to use the words of quaint old Butler, is a "summer bird"; and that, aside from the queen, none lives out a 12-month span.

The age of the individual bees must not be confused with that of the colony. Colonies have been known to occupy the same hives for a great many years. Langstroth mentioned having seen flourishing colonies known to have occupied the same hives continuously for more than 20 years, and relates that the Abbé Della Rocca spoke of some over 40 years old. Such cases have led to the erroneous belief that bees are a long-lived race.

Notched and ragged wings and shiny bodies almost devoid of hairs, instead of gray hair and wrinkled faces, are the signs of old age in the

FIGURE 37. The late Dr. Lloyd R. Watson inseminating a queen bee in his modern laboratory at Alfred, N.Y. (*Photo by O. W. Park*)

bee, indicating that life's work will soon be over. Workers appear to die rather suddenly, and often spend their last hours in useful labor, usually failing to return from the field where they have gone for the last time in quest of stores for the colony. Langstroth has said, "Let the cheerful hum of their busy old age inspire you with better resolutions, and teach you how much nobler it is to die with harness on, in the active discharge of the duties of life."

## Bee Breeding

The desirability of stock betterment is evident from results of the purposeful breeding of corn, wheat, hogs, cattle and many other plants and animals.

### Controlled Mating

Due to inability to control mating, improvement of bees through selective breeding has progressed but slowly. Several approaches to the problem of controlled mating may be mentioned. The numerous attempts that have been made to secure matings in confinement have yielded an insignificant proportion of successful matings. Isolated mating stations have been used with reasonable success, but usually it is difficult to find proper isolation in combination with convenient access and conditions fa-

vorable to bee life; hence this method so far has not been employed extensively except in Switzerland. Hand matings, in which the operator attempts to manipulate queen and drone in a manner that will result in a more or less normal transfer of spermatozoa to the spermatheca of the queen, have been reported successfully performed by Laidlaw,[49] who subsequently gave up that technique in favor of instrumental means.[50]

Instrumental insemination of queens, after many failures, was at last successfully performed by Watson,[51] of Alfred, New York (Fig. 37), and was demonstrated by him at Cornell University and at a meeting of apiarists at Hamilton, Illinois, in 1927. Watson's work in the development of precision instruments and the improvement of technique opened the field of selective breeding, as predicted by C. P. Dadant in 1927. Already the method has been used with varying degrees of success by workers in widely separated parts of the world. Further advances in technique have been made notably by workers in the Division of Bee Culture.[52] The closing paragraph of Nolan's comprehensive summary[53] of the development of bee breeding from 1900 through 1936 reads: "Now that a notable advance in the technique of accomplishing matings has been made, methods for obtaining biometric data have been worked out, and germ plasm that possesses a number of desirable characteristics is available, the way appears open for a worth-while advance in bee breeding, although quick results should not be expected."

### Inbreeding

Inbreeding occurs when relatives are mated together. In the case of honey bees, inbreeding may be intense, as when a drone mates with a queen from the same colony, or it may be slight, as when a drone mates with a queen from another colony in an apiary composed entirely of Italian bees, but coming from widely different sources. Inbreeding has as its only function the purifying of (making homozygous) the inheritance which is to be found within the different races or strains as a result of continuing the inbreeding process. The so-called "disastrous results" of close inbreeding come from the fact that the bad inheritance of a strain, as well as the good, fully expresses itself in the progeny. This bad inheritance is reproduced from generation to generation or, as is sometimes said, the strain "runs out." The "running out" is due not to any effect of the inbreeding on the germ plasm, but to the bad inheritance which

---

[49]Laidlaw, Harry H., Jr. 1932. Hand mating of queenbees. *Amer. Bee Jour.* 72:286.

[50]Laidlaw, Harry H., Jr. 1944. Artificial insemination of the queen bee (*Apis mellifera* L.): Morphological basis and results. *Jour. Morph.* 74:429-465.

[51]Watson, L. R. 1927. *Controlled Mating of Queenbees.* 50 pp. illus. Hamilton, Ill. American Bee Journal.

[52]Mackensen, Otto and W. C. Roberts. 1948. A manual for the artificial insemination of queen bees. *U.S.D.A. Bur. Ent. and Plant Quar. Circ.* ET-250.

[53]Nolan, W. J. 1937. Bee breeding. *U.S. Dept. Agr. Yearbook* 1937:1396-1418. (List of literature cited contains 40 titles.)

in the original strain was covered up by the genes introduced through outbreeding, as ordinarily happens in nature.

The production of good inbred strains of bees depends on controlled inbreeding accompanied by severe selection. If 50 brother-sister crosses are made from a selected good colony, some of the lines will be quite bad, others poor, fair, medium or good. By discarding those lines which prove to be inferior and continuing to breed from the best ones, fairly good inbred strains may often be established. But, if the breeder is not willing or able to make this rigid selection, he had best stay away from the inbreeding process and trust to outcrosses to maintain the quality of his stock.

If the queen breeder is willing and able to do the careful work and stand the losses of controlled inbreeding and rigid selection, possibilities as yet unfathomed but like those in hybrid corn, may be in the making. Selected inbred lines will be freed of their worst inherited defects, and they will be capable of transmitting their good characteristics to most of their progeny. But even with rigid testing and selection, the inbred lines retained will have some defects. These remaining defects may be suppressed in improved strains of honey bees by crossing two inbred strains, which are themselves only distantly related and which complement each other in having good traits in one line for any inferior characteristics in the other. Such a cross corresponds to the corn breeder's single cross. The crossing of more than two inbred lines, such as a three-way hybrid cross, offers further possibilities in developing improved strains of bees.

The establishing of inbred strains is possible only through controlled mating, accomplished either in isolated mating yards or by means of instrumental insemination. Due to the extreme difficulty of finding complete isolation in many queen-rearing areas, and due to the time, expense, and great skill involved in artificial insemination of queens, the breeder, in all likelihood, will find it necessary to look to the several scientific agencies as sources of improved breeding stock. The very means whereby Nature has effectively prevented intense inbreeding in the honey bee—the mating of the queen in the air—has made it difficult for man to make rapid progress toward the development of a better bee.

When once a desirable strain is available, the application of stock-improvement methods by the honey producer becomes relatively simple. The strain of bees in a given apiary may be completely changed in the course of a few weeks during the active season, through the simple expedient of removing the old queen from each colony and introducing a new one of the desired stock.

As in any other branch of livestock, the development of improved strains of honey bees is a job for specialists—men scientifically trained for the task. Then in order that the industry as a whole may benefit, the superior stock must be propagated and made available in large numbers to honey producers. This job also is best done by specialists—the com-

mercial queen breeders. Utilizing isolated valleys of the Alps for mating stations, the Swiss for years have operated a stock-improvement association which has been instrumental in securing widespread distribution and use of better stock among their producers.

### Breeding for Disease Resistance

In our own country the development of a strain of bees resistant to American foulbrood was undertaken in 1935, as a co-operative project supported by the *American Bee Journal,* the Agricultural Extension Service of Iowa State College, and the Iowa Agricultural Experiment Station (Figs. 38, 38a). The development of this project is described in Chapter XXIII, "Diseases and Enemies of the Honey Bee."

As a result of this project, arrangements were made, in 1940, whereby stock thus developed could be made available to some one state agency in every state for purposes of propagation or experimentation, or both. Iowa was the first state to make any considerable use of this opportunity. Under the terms of a mutual agreement, the Iowa Agricultural Experiment Station each year lends some of its choice queens, that have been tested for resistance to American foulbrood, to the Iowa Beekeepers' Association, which assumes the responsibility of providing for the propagation of daughter queens and the distribution of them to the industry.

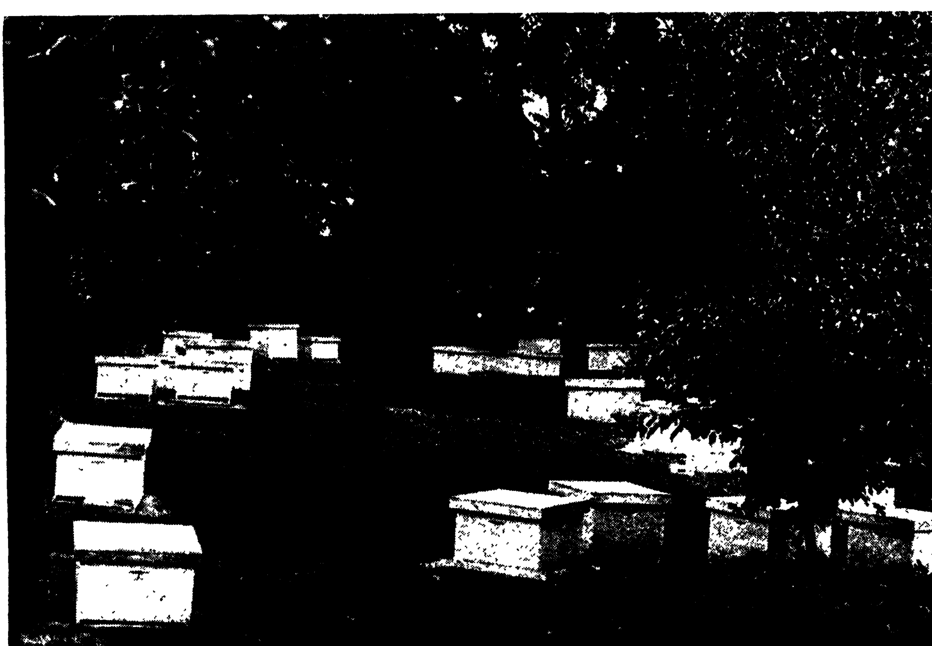


Figure 38. Original setup for determining resistance to American foulbrood and the development of disease-resistant strains of honey bees, located at Pellett Gardens, Atlantic, Iowa. (*Photo by O. W. Park*)

FIG. 38a. One of the apiaries of the Iowa Agricultural Experiment Station at Ames, Iowa, where disease resistance of honey bees was studied. (*Photo by O. W. Park*)

Several other agencies are now taking considerable interest in developing means for utilizing breeding stock possessing desirable characteristics. Queen breeders in the South and in California are becoming more interested in rearing queens from such breeding stock. Many thousands of queens, mated to sons of tested mothers and themselves daughters of tested mothers, have already been distributed.. Some have found their way into beehives in almost every state in the Union and the various provinces of Canada. Such stock has shown itself to be at least the equal of ordinary commercial stock, and vastly superior in its ability to resist American foulbrood. Although the output of this stock has been greatly increased nearly every year since 1940, demand for it continues to be in excess of the available supply. Thus it is apparent that beekeepers are awake to the desirability of using improved stock.

# IV. *Activities of Honey Bees**

BY O. W. PARK†

THE term "colony morale" was coined by the late George S. Demuth who used it to describe what might be referred to as the mass psychology of the colony with reference to its zeal, or lack thereof, in forging ahead with such tasks as the rearing of brood and the accumulation of stores. We recognize that high morale in a football squad is of the greatest importance to a successful season. It is no less important to a successful season in the apiary, but a colony of bees would not be moved in the least by the most forceful "pep" talk that ever transformed a squad of quitters into a team of victors.

Colony morale—high or low—is determined by the response of the colony to the various factors of its environment. Any failure of the apiarist to control and adjust the various factors of colony environment in conformity with the laws of bee behavior tends to lower colony morale; whereas, every manipulation performed in accordance with the normal activities of the colony tends to heighten it. Obviously the beekeeper should be quick to recognize any evidence of low or waning morale, such as bees clustered outside of the hive during the honeyflow, undue slowness in entering supers, or untimely slackening of either brood rearing or the accumulation of stores.

But how is the beekeeper to know when he is violating one or another of the numerous laws of bee behavior? That he can know only by possessing a broad and deep knowledge of the behavior of bees. But what can the beekeeper do when he finds evidence of low morale? There isn't much he can do unless he knows the behavior of bees well enough to figure out what factor or factors in the environment have caused these naturally industrious "creatures of instinct" to "go on strike." How can such knowledge be gained? By wide reading on the subject, coupled with close observations on the bees themselves. Unfortunately, there is no single source for such information; it is widely scattered through the literature.

Maximum honey production depends upon high colony morale which can be maintained only through intelligent management based upon a thorough knowledge of the habits of bees and their instinctive responses

*Publication of the Iowa Agricultural Experiment Station, Ames, Iowa.

†O. W. Park, Ph.D. Research professor of apiculture, Iowa State College. Formerly assistant in zoology, Kansas State College. Formerly associate in entomology and apiculture, University of Illinois. Specialist in studies on the acquisition of food by the honey bee, activities of the honey-bee colony, and resistance to American foulbrood.

to the various stimuli with which they come in contact. The honey producer with a thorough knowledge of the behavior of bees will be able in most cases to discover any offending factor and to modify or eliminate it, thereby improving the colony's morale and collecting good dividends on his investment.

## A Creature of Instinct

The honey bee is largely a creature of instinct. Its responses to the various factors of its environment are, therefore, largely of a machinelike nature. Aside from a limited number of reactions which give some evidence of adaptation, association, memory, and learning, the honey bee responds in a fixed way to a given change in its environment. It never has been and presumably never can be domesticated or made to do man's bidding as have various other animals. Inasmuch as man cannot mold the nature of the bee to his will, his profit from her labors will depend upon his ability to adjust his methods to her ways, and not vice versa.

Years ago, beekeepers in general gave much attention to the study of bee behavior, but in recent times the subject appears to have been largely forgotten by honey producers. Langstroth, Quinby, A. I. Root, Doolittle, Charles Dadant, and C. C. Miller were outstanding students of bee behavior and their writings abound with records of their observations. It is of interest to note that these same men were the practical beekeepers who laid the foundation which today supports the superstructure of modern beekeeping in America.

It has been aptly stated that the beekeeper should invest one part of money and nine parts of brains in his business. If he leaves out the major investment, failure often follows because he lacks the knowledge of activities and reactions of bees which would have enabled him to keep colony morale at a high level throughout the season. Mr. Average Beekeeper is making a costly mistake when he overlooks the benefits to be derived from a thorough knowledge of bee behavior. Benefits arise in two ways: Through maintenance of improved colony morale and through a distinct heightening of the morale of the beekeeper himself. The latter benefit arises from the fact that apiary management then becomes an interesting game instead of routine drudgery.

## Temperature and Its Relation to Activities of the Honey Bee

Temperature exerts an important influence upon the activities of the honey bee. Butler (1609) wrote advisedly when he called the bee "a summer bird," for only rarely does a honey bee perform any useful work at temperatures below 50° or above 100° F. At temperatures closely ap-

proaching 100° or above, bees seldom go to the field but remain idle within the hive or cluster listlessly on the outside. A single inactive bee soon loses the ability to fly at 50° and at temperatures below 45° soon loses all power of motion. But the honey-bee *colony* possesses the ability to maintain and regulate its own temperature to a remarkable degree and, therefore, does not need to hibernate during cold weather as do other insects. In fact it long since has lost its ability to do so.

The honey bee is one of the very few insects known to be unable to hibernate. It seems certain, therefore, that at one time it, too, must have shared that faculty. We may surmise that the loss of this power came about through disuse, as the result of the evolutionary development of other and more valuable traits which have contributed to the success of the honey bee in its competition with other forms of life. Acquisition of the ability virtually to make its own temperature environment has given the honey bee the power to remain active and even to carry on reproduction practically the year round, in all but the coldest climates. This faculty has enabled the honey bee to reproduce itself in numbers that are vast in comparison with the reproductive output of most of its competitors.

## Evolutionary Trends

Among evolutionary trends that have helped the honey bee to develop its ability to maintain and to regulate temperature are the following: 1. Development of well-organized social units—*colonies*. 2. Habit of using a sheltered environment for a home—cavern, hollow tree, or *hive*. 3. Specialization in the production and use of a heat-producing food—*honey*. 4. Development of a food-storage organ—*honey sack*. 5. Habit of *storing* food far in excess of current needs. 6. Habit of *clustering* at low temperatures, thus providing for conservation of the heat generated by the individual bees.

Honey, which is practically the only food of the adult honey bee, is composed almost wholly of sugars which are transformed into heat very quickly after being consumed. The honey sack makes it possible for the bee to maintain within its body a ready supply of honey, which can be released as required for the production of heat. The habit of storing honey within its nest far in excess of immediate needs normally provides for an ample and constant supply of this efficient fuel for use during any period of nectar dearth but especially for use during winter. But all of these excellent provisions would go for naught without the benefit of the habit of forming in cold weather a compact cluster of all the bees in the colony. By this means the heat generated by the individual bee is conserved, and regulated by the simple expedient of varying the compactness of the cluster.

We are familiar with the fact that small objects lose heat far more rapidly than large ones, and that loss of heat by radiation and conduction is proportional to the area of the surface and inversely proportional to the

mass. If the dimensions of a body be increased from 1 to 2, the area is increased from 1 to 4 while the cubic content is increased from 1 to 8. Thus a large body has far less surface than a small one in relation to its size, so that its heat loss occurs more slowly, as well as because of its greater mass. For these reasons a single bee has little power to retain the heat it is able to generate when exposed for any considerable time at low temperatures. But the clustered colony, composed of many thousands of these small individuals, is able to maintain warmth and activity even in extremely cold weather.

### Activities Requiring Uniformly High Temperatures

While bees are able to perform many of their duties throughout the temperature range already suggested, in general the activity of the honey bee tends to slow down at temperatures below 70° and above 95° F. Under abnormal conditions bees will go out on a cleansing flight or, in case of special need, will attempt to bring in badly needed supplies of food or water at temperatures somewhat below 45°. Many bees fail to return from such missions. Parks[1] reports that bees will gather pollen and nectar at temperatures as low as 42°. Some years ago the author[2] observed bees in early spring leaving their hives when the temperature of the air was 33° and returning with loads of ice water (32°) obtained from puddles formed by melted snow in the apiary.

The mating flights of the queens and drones and the orientation flights (so-called play flights) of young bees normally are restricted to temperatures that are definitely mild and comfortable as judged by human standards. Wax secretion, comb building, and brood rearing require considerable warmth as well as considerable uniformity of temperature. While optimum temperatures for these activities probably are not far from 92° to 93°, possible limits may be as low as 85° and as high as 97° F. This does not mean, however, that the temperature throughout the hive is uniformly high when these activities are in progress, but rather that the required temperature is maintained in such parts as are devoted to these activities at the time.

### Temperature Responses of the Broodless Winter Cluster*

Toward the close of the active season, brood rearing decreases until it ceases altogether in late fall. At this time, bees in a broodless colony remain relatively inactive on the combs and generate practically no heat so long as the temperature of the air surrounding them remains between 57° and 69° F. At temperatures either above or below this range activity

[1]Parks, H. B. 1925. Critical temperatures in beekeeping. *Beekeepers Item* **9**:125-127.

[2]Park, Wallace (O. W.). 1923. The temperature of the bee's body. *Amer. Bee Jour.* **63**:232-234.

*The discussion of temperature responses of the broodless winter cluster is based primarily, but not exclusively, upon observations reported by E. F. Phillips and George S. Demuth, "The Temperature of the Honeybee Cluster in Winter," *U.S.D.A. Bull.* **93**, 1914.

increases. Above 69° such activities vary but they often result in many bees taking a flight. Whenever the temperature surrounding the bees falls below 57°, the bees congregate in a compact cluster within which the temperature is raised by heat generated by the bees. Within the cluster the bees are able to continue the activities which are essential to their survival. As the temperature outside the cluster continues to drop, that within begins to rise, and the colder the weather the higher the temperature developed within the cluster. When the temperature outside the cluster rises above 57°, the cluster disbands, but it will form again whenever the surrounding air cools below this critical temperature.

The winter cluster, when first formed, usually is located in the lower part of the hive, often near the front. Throughout the course of winter, it moves upward and to the rear of the hive. By spring the cluster in a two-story hive is found most often in the upper story. The shape of the cluster is approximately spherical but, of course, is not continuous because of the several combs that pass through it. An outside shell composed of a variable number of layers of bees packed closely together provides the insulation needed to conserve the heat generated within the cluster. Nearly all of the bees in this outer shell have their heads directed toward the center of the cluster. They move about very little while those within the cluster enjoy considerable freedom of movement. This both facilitates the distribution of food and provides for the necessary generation of heat by metabolic processes which at times may be stepped up by muscular activity. For additional information on the winter cluster, see Chapter XIV, "The Overwintering of Productive Colonies."

## Division of Labor

"They divide the work, as it has been already said; some work at the honey, others at the grubs, and others at the bee bread; some, again, form the comb, others carry water to the cells and mix it with the honey, while others go to work"—so wrote Aristotle[3] more than 3 centuries B.C. with reference to honey bees. From time to time, subsequent authors have elaborated on the topic of division of labor in the honey-bee colony.

### On the Basis of Sex

The most fundamental segregation of duties, of course, is based upon sexual and physiological differences in the three castes. The drone is the male, whose sole function is that of mating. The functions of motherhood are divided between the other two castes, queen and worker; both are of the female sex but they differ widely in size, structure, and duties. The work of a queen is restricted to the laying of eggs, while all the other functions of a mother, including incubation of eggs, nursing, and other-

[3]Aristotle. 1907. *History of Animals*. Bk. IX. p. 267. Cresswell Trans. London.

wise caring for and protecting the young, are delegated to the workers. Upon workers devolve also all the other duties of both hive and field.

During its early evolutionary development, the honey-bee colony in all probability consisted of but two types of individuals, male and female. At that time each female laid a few eggs and worked in the field as well as within doors, much as queen bumble bees have to do in early spring while rearing their first brood of workers. In the course of events certain females became more prolific than others and devoted more of their energies to egg laying with a corresponding reduction in the exercise of other maternal functions. Concurrently with this change another type of female was in the making. Most females, being less proficient at egg laying, tended to spend less and less of their time at this task, and devoted themselves more and more to field work and to the performance of household duties including the secretion of wax, building of comb, and nursing the young. In some such manner there came to be two female types or castes in the honey-bee colony.

Those strains of honey bees, in which diversification, specialization, and division of labor developed ages ago, became more prosperous than others and in general were better able to compete in the struggle for existence. Their success in this life-and-death struggle is attested by the pre-eminence of their descendants in the insect world of today.

### On the Basis of Age

Division of labor in the honey-bee colony is not, however, restricted to that based upon caste differences. The various duties of hive and field, except one each delegated to the queen and her consort, are systematically apportioned among the workers. Although for centuries it has been accepted as a fact that such duties are divided among the workers, the basis for apportionment remained a secret until relatively recent times. But for some years now it has been established beyond doubt that the broad fundamental basis for allotment of duties among workers is the physiological age of the individual. Consequently, in the course of its lifetime each worker normally would perform successively each of the numerous tasks executed by the worker caste.

Stray bits of information have been in the literature for years, but the most comprehensive work in this field to date is that of Rösch[4,5,6] of Germany. His investigations, reported in 1925, 1927, and 1930, have supplied several missing links, confirmed various conceptions based upon reports of previous observers, and in general rounded out a fairly satis-

[4] Rösch, G. A. 1925. Untersuchungen ueber die Arbeitsteilung im Bienenstaat. 1. Teil: Die Tätigkeiten im normalen Bienenstaate und ihre Beziehungen zum Alter der Arbeitsbienen. *Ztschr. f. vergl. Physiol.* 2(6):571-631.

[5] Rösch, G. A. 1927. Ueber die Bautätigkeit im Bienenvolk und das Alter der Baubienen. *Ztschr. f. vergl. Physiol.* 6(2):264-298.

[6] Rösch, G. A. 1930. Untersuchungen ueber die Arbeitsteilung im Bienenstaat. 2. Teil: Die Tätigkeiten der Arbeitsbienen unter experimentell veränderten Bedingungen. *Ztschr. f. vergl. Physiol.* 12(1):1-71.

factory picture of the systematized life and duties of the worker bee. The results of his studies include extensive data relative to the age at which marked individuals were found to engage in various activities either within or without the hive.

As noted by previous observers, Rösch found that, during the most active season of the year, workers live 5 or 6 weeks and that approximately the first half of the worker's life is occupied by duties *within* the hive, while the latter half is spent in *field* work. During the first 13 days after emergence, the worker normally performs but two kinds of work, but from the fourteenth day through the twentieth day she may vary her occupation to a considerable extent within certain fairly well-established limits. Furthermore, no hard-and-fast time limits are given for the various duties; an excess of bees for any given work may lead to the performance of other duties, or a shortage of help in a given line may bring about a departure from the normal sequence of duties. As a matter of fact, it has been known for years that a colony containing no workers more than 8 days old is capable of performing all the functions of a normal colony.

Bees 1 to 3 days old were observed to clean themselves upon emergence, take food from other bees but none from the cells of the comb, clean out brood cells, and loiter upon the brood, thereby helping to keep it warm. Their loitering upon the brood appears to be of considerable importance since the duties of other bees take them away from the brood in the busy season. The only work performed during this period is that of cleaning brood cells. Workers of this age were never seen helping themselves to any food stored in the hive. At 3 to 6 days of age they act as nurse bees, but feed only the older larvae that are not more than 2 days under the age for sealing, feeding them pollen and honey* which they take from the cells. But when the glands which secrete brood food become functional, a development which occurs at the age of about 5 or 6 days, they then feed principally the younger larvae, continuing until about the thirteenth day.

Orientation flights often begin during the latter part of the nursing period, which may extend slightly beyond the thirteenth day in case of lack of nurse bees. Or it may be cut short by a heavy honeyflow, for the second and final period of hive duties begins with relieving incoming nectar gatherers of their loads and storing them away. The storing away of pollen is performed at this age also and, once these duties are begun, the job of nursing is left to others.

With the decline of the brood-nursing glands, which starts somewhat before the thirteenth day, the wax glands begin their functioning and are at the height of their development in workers from 12 to 18 days old. And as might be expected, it was found that comb building is done

---

*Haydak (see reference No. 8 in Chapter III) is of the opinion that the production of either a queen or a worker is due not to any change in the character of the food itself, but rather to the amount of essential nutrients consumed by queen and worker larvae.

largely by workers of this age. Still other tasks performed during this, the second and last period of hive duties, include cleaning the hive and carrying out debris and, finally at 18 to 20 days of age, guarding the entrance. According to Rösch, bees of this age often sit idle on the combs or perform all kinds of incidental work which may be carried on for a short time only. Thus it will be seen that no definite statements can be made as to the behavior of a worker during the third week of her life.

Working with marked bees of known ages in a colony containing bees of all ages, Nelson[7] found that, during the first and second days of their lives, young worker bees devote their time to taking food, cleaning themselves, remaining quiet and motionless on the comb, and in some cases resting in the cells. No nursing activities were observed in bees of this age. On the third day after emergence he found them polishing cells, ministering to the queen, manipulating nectar with their mouthparts, nursing larvae, and assisting with the construction of cappings over cells, some of which contained brood and others honey. He observed that orientation flights were made by bees as young as 4 days and 2 hours. The youngest bees observed with wax scales were between 8 and 9 days old. Nelson's observations revealed considerable shifting from one activity to another among workers between 3 and 12 days old.

Haydak,[8] likewise using marked bees of known ages, found that, in the absence of older workers, bees 1 day old were able to seal cells. At 2 days they fed older larvae and at 3 days carried out rubbish and acted as guards. Even 1-day-old bees attempted to attack robbers. The first orientation flights occurred at the age of 3 to 4 days. He found also that workers 4 days old would collect pollen when there were no older workers and no pollen in the hive. Both Nelson and Haydak report data which strongly suggest that, to a considerable extent, bees which differ rather widely in age are able to adapt themselves to the needs of the case; and by the time Rösch published his 1930 paper he, too, had arrived at the same conclusion.

Some observers have stated that the carrying of water is the first field duty performed. Others hold that pollen is the first substance carried, while several feel sure that the gathering of nectar is the last duty to be undertaken by the worker. Wiltse[9] and Nelson[10] both made observations on abnormal colonies composed of young bees only. Wiltse found that the first material to be brought in was water, then nectar and pollen in the order named. Nelson found the same order for nectar and pollen and

---

[7]Nelson, F. C. 1926. *A study of the methods of marking honeybees and division of labor in the colony*. Unpublished thesis. Univ. of Ill., Urbana, Ill.

[8]Haydak, Mykola H. 1932. Division of labor in the colony. *Wisconsin Beekeeping* **8**(5): 36-39. Reviewed: 1932. *Bee World* **13**:93.

[9]Wiltse, Jerome. 1882. Work done by two quarts of bees before 16 days old. *Gleanings in Bee Culture* **10**:596-597.

[10]Nelson, F. C. 1927. Adaptability of young bees under adverse conditions. *Amer. Bee Jour.* **67**:242-243.

suspected that some of the first loads were water, but says they may have been nectar. Rösch failed to find any definite sequences in duties performed outside the hive. Apparently the duty performed depends upon circumstances.

More studies along this line are needed to fill out the picture of division of labor in the honey-bee colony. The present picture is sketchy and lacks much of being complete. It is stated, for instance, that workers shift from one job to another as occasion demands, but what is the answer to the question: How does the worker find out what each occasion demands of her?

## Wax Secretion and Comb Building

It has been observed already that the kind of work performed depends largely upon the age of the worker. The first 3 weeks of her adult life (about 6 weeks during the honey-producing season) are devoted to activities within and in close proximity to the hive while the remainder is given over to work in the field. Thus in summer a worker spends one half of her life as a house bee and the other half as a fielder.

Of the many kinds of work carried on within the hive, comb building and brood rearing may be considered major activities. They fulfill fundamental biological needs—shelter and reproduction, respectively. Certain other types of work may involve comparable numbers of individuals but possess far less biological significance.

### Secretion of Wax

The material used by honey bees in the construction of their combs is a product of their own bodies. It is secreted by certain glands possessed by workers only. As already stated, wax glands are at the height of their development and productivity in bees 12 to 18 days old. The wax appears in the form of small, irregularly oval flakes, or scales, which project from between the overlapped portions of the last four abdominal segments visible on the underside of the bee. Two scales are produced on each of these segments, one on either side of the midventral line, making eight in all. Wax can be secreted only at relatively high temperatures (stated variously by different authors at from 92° to 97° F.) and after the consumption of relatively large amounts of honey or nectar. Thus, indirectly, beeswax is derived from flowers, but is not gathered directly from them as was believed by the ancients.

Various attempts that have been made to determine the amount of honey consumed in producing 1 pound of wax indicate that anywhere from about 5 to 25 pounds may be required. This may seem like a wide variation but, since neither very young nor very old bees are well fitted physiologically for wax secretion, it is to be expected that the efficiency of a colony in wax production would be greatly influenced by the presence

or absence of a suitable force of workers of the right age. While it is known that older bees can and do secrete wax when necessary, it seems a reasonable assumption that their efficiency would be low, resulting in a correspondingly high consumption of honey. Recent studies by Whitcomb[11] using four queenright colonies, approximately equal in population, showed that in building comb from foundation the least productive colony used 8.80 pounds of honey per pound of wax produced; the most productive used only 6.66 pounds; and the average for the group was 8.40 pounds of honey.

Formerly it was believed that bees require pollen in their diet in order to produce wax, but Huber[12] demonstrated that this assumption was unfounded. It seems probable, however, that pollen as well as honey may be required for the most efficient production of beeswax (see Chapter V entitled "The Honeycomb").

### Manipulation of Wax Scales

Workers actively engaged in secreting wax gorge themselves with honey and hang in festoons at or near the site of building operations. Here they hang very quietly while their organs of digestion and secretion transform the content of their honey sacks into energy and beeswax, and after about 24 hours they begin to build comb.

The following description of how bees manipulate wax scales and build comb is based largely upon the excellent studies of Casteel.[13] For illustrations and other information on the structure and functioning of the wax glands, see Chapter XIX, "The Anatomy of the Honey Bee."

Wax scales, unless lost by accident, always are removed from their "pockets" and manipulated by the bee that secretes them, although scales that have been dropped sometimes are recovered and used by others. Contrary to earlier conceptions, the so-called wax shears play no part in the handling of wax scales which, literally, are forked out of their pockets (Fig. 39) by means of the spines on one or the other of the hind tarsi (Fig. 42). While the scale is thus held, the hind leg bearing it is flexed toward the mouth, where the scale may be grasped conveniently by the fore legs or by the mandibles (Figs. 40, 41). Bees do not follow any definite sequence in the order in which they remove scales from the several pockets.

Usually the fore legs assist in transferring the scale to the mandibles, and they also manipulate the scale during the thorough mastication given it by the mandibles before it is affixed to the comb. It is supposed that the wax of the scale, as secreted, differs slightly in chemical composition from the wax in the comb. This change is attributed to the masticating

[11] Whitcomb, Warren, Jr. 1946. Feeding bees for comb production. *Gleanings in Bee Culture* 74:198-202,247.

[12] Huber, Francis. 1926. *New Observations on Bees*. Trans. by Dadant. 230 pp. Hamilton, Ill. American Bee Journal.

[13] Casteel, D. B. 1912. The manipulation of the wax scales of the honeybee. *U.S. Bur. Ent. Circ.* 161.

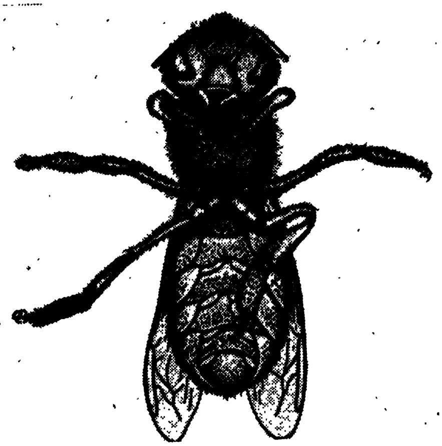


FIGURE 39. Ventral view of a worker bee in the act of removing a wax scale. The two middle legs and the right hind leg are used for support, while the left hind leg removes the scale. (*After Casteel*)

FIGURE 40. Ventral view showing the position of the wax scale just before it is grasped by the fore legs and the mandibles. The scale is still adhering to the spines of the pollen combs. (*After Casteel*)

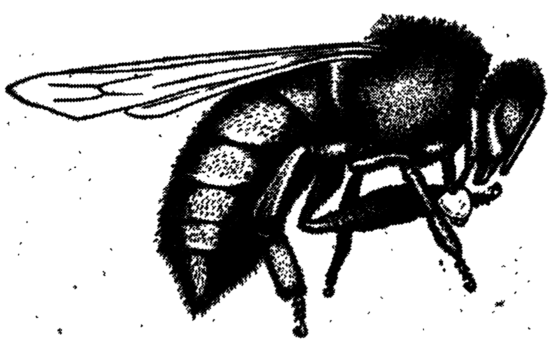


FIGURE 41. Side view of worker bee in the same position as that shown in Figure 40. (*After Casteel*)

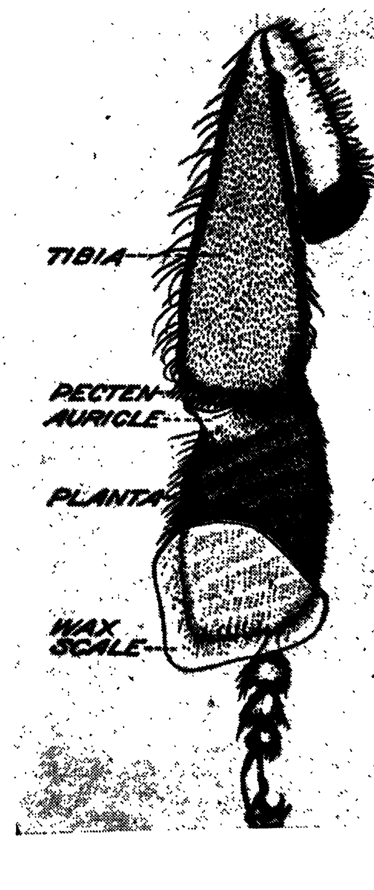



FIGURE 42. Inner surface of the left hind leg of a worker bee, showing the position of a wax scale immediately after it has been removed from the wax pocket. The scale has been pierced by seven of the spines of the pollen combs of the first tarsal segment or planta. "Planta" as here used is the *basitarsus* of Snodgrass (see Figs. 244 and 245 in Chapter XIX, "The Anatomy of the Honey Bee"). (*After Casteel*)

process during which the wax is mixed with saliva, becomes translucent instead of transparent, changes slightly in color, and increases in pliability.

Scales that are small and thin may be masticated completely before any wax is added to the comb, but if large and thick a portion only may be prepared and added to the comb before the remainder is given similar treatment. Occasionally, "careless" bees will mix small unchewed portions of scales, or even entire scales that are practically unprocessed, with the masticated wax of a newly constructed comb. When first deposited by the producing bee, masticated wax is spongy and flaky but later it is reworked and thereby becomes smoother and more compact. The whole process of removing, masticating, and affixing one scale to the comb requires about 4 minutes.

## Comb Building

It has been stated by some investigators that the wax is sculptured by bees other than those that produce it, which is to say that producers and builders are distinct classes of laborers. This was found to be only partially true for, although old bees devoid of wax scales were observed to perform an important part of the labor of reworking newly deposited wax, young bees with well-developed wax scales protruding often were found to be more busily engaged in working wax than in producing it. Furthermore it was found that the work of sculpturing and polishing the comb is not

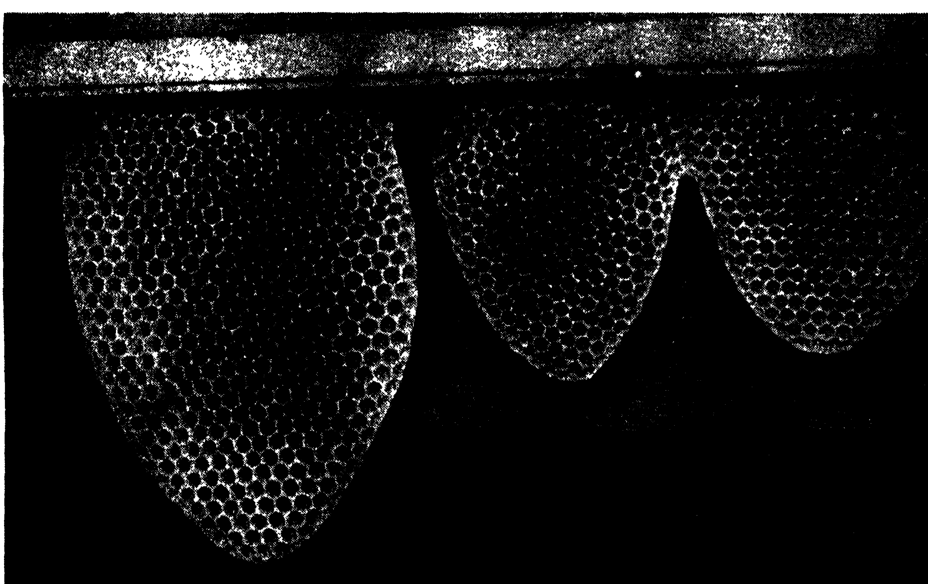


FIGURE 43. Combs built without comb foundation, showing three U-shaped areas which have been separate centers of activity for groups of comb builders. The adjacent areas of the two combs at right are already being joined together, as will all three eventually to form a single comb. Note that the cells in the two outside combs are built with the hexagons pointing vertically, while those in the center comb point horizontally. (*Photo by F. C. Pellett*)

a monopoly of non-wax-producing bees, but that these tasks are freely participated in from time to time by wax producers apparently without regard to the number or size of scales in their wax pockets.

The reworking of wax is one of the most characteristic features of comb construction. It goes on constantly while new comb is being built, and it is a necessary process in the reconstruction of old comb.

Comb construction usually proceeds from the top downward though not necessarily so. In nature, construction often is started at two or more points a few inches apart along a line which may or may not be straight. Other combs may be started simultaneously with the first (Fig. 43) and usually are parallel to it at distances of approximately 1½ inches from midrib to midrib. Each of these several points is the center of activity for a group of workers composed of both wax producers and builders. As the several small units of comb in any one line increase in area, the edges of adjacent small combs meet and are joined together so that eventually all of those in one line form a continuous comb. Such construction results in vertical seams composed of odd-shaped and irregular "accommodation" cells that may be observed in many natural-built combs. For additional information on comb building, see Chapter V entitled, "The Honeycomb."

## Brood-Rearing Activities

### Egg Laying

Egg laying, as already mentioned, is the special function and virtually the sole activity of the queen. A good queen works in an orderly fashion, affixing a single egg to the base of each cell and leaving but few vacancies within the area worked. No doubt she inadvertently misses a cell now and then, but some of the vacancies are to be accounted for by the fact that she inspects each cell before laying in it and rejects such as are not clean and well polished. Upon satisfying herself that the cell is clean and unoccupied, she withdraws her head, moves slightly forward, arches her abdomen, and deftly inserts it until contact is made with the cell base. In this position she remains motionless for a brief interval (Fig. 44), pivots partially around the cell she occupies, and withdraws.

While the above procedure sometimes is completed in 10 seconds or even less, it is not to be assumed that any queen maintains such a rate for long. It is now a well-established fact that even the most prolific queens seldom lay in excess of 1500 eggs per day, or just about one per minute. Queens, however, do not lay continuously but work for a while, then rest for a while. At times an active queen will deposit an egg about every 10 or 15 seconds until she has laid perhaps 75 or 100 eggs, when she will desist for some minutes to rest and take food.

A queen can, and not infrequently does, take honey from a cell, but when actively engaged in laying she is fed by the workers which supply

FIGURE 44. The queen, as indicated by the arrow, has her abdomen inserted into a cell and is about to lay an egg in it. ("*Honey Bee*," *Encyclopædia Britannica Films Inc.*)

her with the glandular secretion called royal jelly. This highly nitrogenous substance is produced principally by workers between the ages of 5 and 13 days, as has been noted already, but can be supplied in limited quantities by older bees. Whenever the queen pauses in her labor, near-by workers supply her with food, groom her, stroke her with their antennae, and in various ways wait upon her. At such times it is not unusual to find the queen surrounded by a circle of these so-called attendants with their heads toward her. Whenever such a circle forms, it is composed of workers that chance to be near the queen. This suggests that they may turn toward her in response to an odor stimulus whereby they recognize her close proximity. The circle of attendants disappears when the queen resumes laying or moves elsewhere, but wherever she goes many of the near-by workers turn toward her as she passes.

## INCUBATION

Except in warm weather, bees generate and conserve heat for the incubation of brood, just as they do for the maintenance of the broodless cluster in winter. The first brood of the season is reared within the winter cluster usually in late winter or early spring. During cold weather, only small amounts of brood can be reared because of the limited space that can be kept sufficiently warm. But as the season advances and outside temperature increases, the cluster can expand to cover additional brood space and yet maintain the required temperature. The resulting increase

in colony population also accelerates expansion of the space devoted to brood rearing. With further increases in outdoor temperature, the need for producing and conserving heat is reduced to such a point that there seldom is need for a well-defined cluster. So in warm summer weather, such additional heat as may be needed for incubation is supplied largely by the bodies of young bees, especially the nurse bees and the newly emerged adults, as they go about their respective duties or simply "sit" on the brood, as the case may be.

The optimum temperature for brood rearing usually is stated as 93° F. but temperatures considerably lower and somewhat higher are neither rare nor harmful. Milum[14] found that temperatures up to 91° or 92° apparently are necessary to stimulate a colony to begin brood rearing, but that temperatures considerably lower than this do not interrupt brood rearing after it has begun. During early spring, temperatures of 85° are not uncommon in parts of the brood nest while, in late spring and in summer, temperature variations usually lie between 90° and 95°. Temperatures as low as 76.3° had no apparent ill effect other than to retard the rate of development. The highest brood-nest temperature recorded was 97.5°. Temperatures above 95° tended to cause the bees to hang outside the hive and loaf.

Milum's temperature studies throw additional light upon the extent of variation in the rate of brood development under extremes of temperature found in the brood nest. Time required for brood to reach maturity was found to vary with its distance from the center of the brood nest. Thus, at the very center where it is warmest, development was completed in the least time; while at the periphery where lowest temperatures prevail, the developmental period was longest. Abnormally high brood-nest temperatures shortened the developmental period of workers by as much as 1 day, and exceptionally low temperatures lengthened it by as much as 3 days, using 21 days as the accepted average for development of worker brood at normal brood-nest temperatures.

### Nursing

Young bees, as previously stated, take up the work of nursing at the age of about 3 days. At first they feed only the older larvae (those over 3 days old), but upon reaching an age of about 5 or 6 days they begin to feed the younger larvae principally, leaving the feeding of the older ones mostly to their younger and less-experienced sisters. The nursing activities of the individual begin to slow down along with the decline of the functioning of their brood-nursing glands, which begins somewhat before the thirteenth day. Although workers beyond this age still are capable of performing nursing duties to a limited extent, most of them turn to other duties at about this time. The following description of the

[14]Milum, V. G. 1930. Brood-rearing temperature and variations in developmental periods of the honeybee. *Rpt. Ill. State Beekeepers' Assn.* **1929**:72-95.

activities of nurse bees is based upon the observations of Lineburg[15] except as otherwise indicated.

The attention bestowed upon eggs and larvae by nurse bees consists in visits to the cells for the purpose of determining the needs, if any, of the cell occupant and for supplying food and care. Activities of the former type may be referred to as *inspection visits,* while those of the latter are considered *nursing visits.* When the time spent in a cell was less than 2 seconds, the visit was considered an inspection; when the visit was of longer duration, it was classed as a nursing visit. Because the actual behavior in the two instances is more distinctive than the difference in time would indicate, the time basis does not appear so arbitrary to the observer. It is undoubtedly true that most inspection visits are completed in less than 2 seconds.

Nurses begin to make inspection visits to the cell as soon as the egg is laid, and continue them at frequent intervals throughout the duration of the egg and larval stages. The need for such constant watchfulness with respect to eggs appears to be due to the fact, first reported by Robbins,[16] that the larva, when ready to hatch, is unable to free itself of the egg membranes until larval food is supplied. This observation has been substantiated by other competent observers, including Bertholf[17] and Lineburg.[18] Thus feeding visits begin promptly, as soon as the tiny larva is ready to emerge from the egg.

During its first 2 days out of the egg, the nurse bees keep the tiny larva supplied with far more food than it can consume, so that it appears to float in the milky-white food. During the third day (Fig. 45), somewhat less food is provided in advance of needs, so that by the end of that day all excess has been consumed; and thenceforth a larva in a worker cell receives food only at intervals. The two types of feeding are distinguished as *mass feeding* and *progressive feeding,* respectively.

Inasmuch as no significant amount of food is ever found in the base, or on the sides of a cell containing an older larva, it was assumed that the usual method of feeding larvae of this age must be directly to the mouth. But King,[19] who succeeded in making observations on the feeding of larvae of all ages in a cross-sectional hive, reports that the attendants never were seen to place food directly into the mouth (Fig. 46). On the contrary, he repeatedly observed food being placed as near the caudal end as to the head of the larva, apparently being placed at random. It was found that the larva then obtains the food by slowly twisting about until its head makes contact with it.

---

[15]Nelson, J. A., A. P. Sturtevant, and Bruce Lineburg. 1924. Growth and feeding of honeybee larvae. *U.S. Dept. of Agr. Bull.* **1222**.

[16]Robbins, R. B. 1887. Making eggs hatch when taken from the bees. *Gleanings in Bee Culture* **15**:42-43.

[17]Bertholf, L. M. 1925. The moults of the honeybee. *Jour. Econ. Ent.* **18**:380-384.

[18]Lineburg, Bruce. 1925. Hatching of honeybee larvae. *Gleanings in Bee Culture* **53**:18-20.

[19]King, G. E. 1928. *The larger glands in the worker honeybee. A correlation of activity and physiological function.* Unpublished thesis. Univ. of Ill. Urbana, Ill.

Lineburg's studies show that both the egg and the larva are under almost constant observation and care of the nurses, and that there is little likelihood of any individual being overlooked for any considerable period. The nurses visit cells containing eggs just about as frequently as they do those with larvae under 4 days of age. During the 8-day period from the laying of the egg until the full-grown larva is sealed within its cell, nurses visit the individual an average of about 1300 times daily—more than 10,000 visits in all. On the last day before the cell is capped, they visit it nearly 3,000 times, spending a total of approximately 4¾ hours within the cell.

Nelson and Sturtevant (see reference No. 15 in this chapter) point out that Lineburg's data show a remarkable correlation with their rate-of-growth data from the third day on. Their studies also demonstrate that larval food is assimilated rapidly and has exceptionally high nutritive value. Within a period of 4½ to 5 days, the worker larva increases its initial weight more than 1500 times. Were a human child, weighing 7 pounds at birth, to grow at the same rate, a heavy-duty truck would be needed for its perambulator before the end of the first week.

The origin and nature of larval food have been discussed in the preceding chapter. Nothing definite can be reported concerning the time and energy expended by nurse bees in elaborating this potent food, but Lineburg suggests that considerable time may be required for its production. Thus it is quite possible that a nurse bee, though apparently idle as far as can be judged from appearances, may be physiologically active in the

FIGURE 45. A nurse bee with outstretched tongue supplying royal jelly to a larva approximately 3 days old. In this instance, she is not supplying the food directly to the larva, but on the side of the cell, close to the larva. ("*Honey Bee*," *Encyclopædia Britannica Films Inc.*)

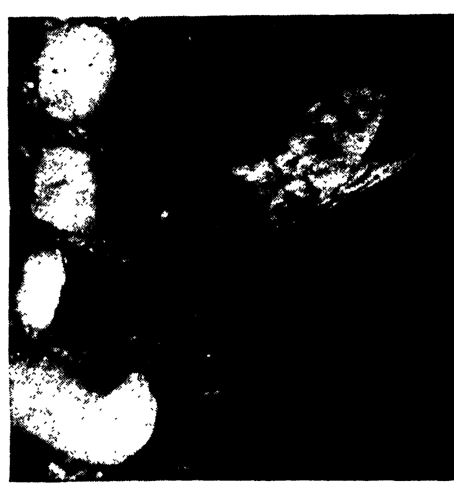


FIGURE 46. A nurse bee feeding a larva that is somewhat older than those in the illustration at left, probably about 4 days old. She is just ready to deposit food directly onto the larva, about the middle of its length. ("*Honey Bee*," *Encyclopædia Britannica Films Inc.*)

production of larval food. Furthermore, the time spent within the cell by nurse bees is relatively great, so, in the absence of detailed studies, we may conclude only that a single nurse bee is able to care for but a few larvae.* Thus a large force of nurse bees is required by a colony if it is to rear a field force capable of gathering a profitable honey crop for the apiarist, in addition to supplying its own food requirements for the inactive season.

## Other Activities of the Younger Bees

All but a very few of the activities of younger bees are carried on exclusively within the hive. The others are performed either near the entrance, or other opening, or else in the air in the immediate vicinity of the hive.

The very first job that faces every young adult is that of extricating itself from its sealed cradle. This it accomplishes by biting away enough of the capping to enable it to push its way out. Lineburg[20] appears to have been the first to report that the bits of capping, thus removed during the process of emergence, are not cast aside as has been assumed. He observed that after some mastication many tiny wads of capping material are stuck fast to the inner surface of the cell near its mouth, especially in the corners. Thus capping materials are conserved and used again and again.

### Cleaning Operations

Bees behave as if motivated by the maxim: "Cleanliness is next to godliness." No inconsiderable part of the worker's life is devoted to cleaning operations of one kind or another. No sooner has she crawled unsteadily from the cradle in which she passed her immaturity than she begins to clean and groom herself. The newly emerged worker presents a somewhat bedraggled appearance, reminding one just a little of a drowned rat, but she dries out quickly and soon begins to improve her appearance. Using her bristle-lined legs, she brushes out the matted or disarranged hair that covers her body. Tongue and mandibles are brought into service also in cleaning and grooming such parts of her anatomy as can be reached.

Conveniently located in the crook of each front leg is an antenna cleaner (see Chapter XIX, "The Anatomy of the Honey Bee"). To use this device, she hooks, let us say, the right fore leg over the right antenna near its base, bends her leg just enough to snugly enclose the antenna, then gently pulls its full length through this special cleaning device. Dirt and dust are removed by this operation much as dirt particles or drops of moisture may be stripped from a rod, encircled by thumb and fingers of

*A bumble-bee queen is able to rear 6 to 16 larvae, and an ant queen, 12 to 15, but in both instances the adults thus reared are undersized.

[20]Lineburg, Bruce. 1923. What do bees do with brood cappings? *Amer. Bee Jour.* 63:235.

one hand, by pulling it through the snug-fitting opening thus formed. When cleaning the other antenna, the device on the other fore leg is used. And all in all, within 24 hours, or even less, our bedraggled young bee has made herself as neat as the proverbial pin.

Aside from taking food, the next undertaking of a young worker is the cleaning and polishing of brood cells in preparation for reoccupation. This is an important duty and not to be slighted, for the queen examines each cell and refuses to lay in any but those that are bright and shiny. Rarely, if ever, does a worker clean the cell from which she emerged, this task being performed by others while she is grooming herself. And several different bees may at separate times work at cleaning a single cell. The actual procedure of cell cleaning is not readily observed, so information is meager. But, judging from the results accomplished, there can be little doubt that both tongue and mandibles are employed, the former for licking the interior of the cell and the latter for packing and "troweling down" the cast skins left at the base. According to both Rösch (see reference No. 4 in this chapter) and Philipp,[21] the interior surfaces of brood cells are "varnished" anew after each occupancy with a substance (see "Activities of Propolis Worker" in this chapter) that is applied with the tongue. As is well known, cells recently renovated present a highly polished appearance, a fact which lends credence to the above report. Also, observations by the author during the past 15 years in connection with investigations on resistance to American foulbrood indicate that the "charwomen" of the beehive are able to do an astonishingly thorough job of renovating dirty brood cells.

When, in the normal course of events, a house bee takes up the duties of a nurse at the age of about 3 or 4 days, her activity in cell cleaning is curtailed, but may be resumed as occasion demands. And during her third week, a house bee works part time as a member of the sanitary corps. This group specializes in removing from the hive dead bees, dirt, and other debris. Objects that are not too large or too heavy they pick up with their mandibles, carry outside, take wing, and drop them at a distance from the hive. Those too large to be carried are often dragged to the edge of the alighting board and pushed overboard. Objectionable items too large to remove, especially dead animals, such as snakes and mice, commonly are "embalmed" with propolis.

### Ministering to the Queen

The work of caring for the needs of the queen is performed largely by the younger bees, in some instances beginning as early as the third day after emergence. As noted previously, the duties of ministering to the needs of the queen are not delegated to particular individuals but are performed from time to time by such workers as may find themselves near

[21]Philipp, P. W. 1928. Das Kittharz, seine Herkunft und Verwendung im Bienenhaushalt. *Biol. Zentbl.* **48**:705-714. Reviewed: 1930. *Amer. Bee Jour.* **70**:274.

FIGURE 47. The worker bee in front has been grooming the queen. The worker bee at right apparently has just offered food to the queen as indicated by the spreading of her mandibles. (*Photo by O. W. Park*)

FIGURE 48. The far worker bee is grooming the queen while, with outstretched tongue, the queen takes food from the worker bee at right. The laying queen lives exclusively on royal jelly. (*Photo by O. W. Park*)

the queen when she pauses among them. The principal services required are feeding and grooming (Figs. 47, 48).

At periods when the queen is not laying and, therefore, needs subsistence only, it may be presumed that her diet is largely, if not entirely, honey which she usually obtains from a near-by worker but in some instances takes directly from the cell. But when actively engaged in laying, she is thought to live exclusively on royal jelly which is supplied to her in abundance by house bees engaged primarily in feeding the larvae, but which stand ready at a moment's notice to feed the queen should she "ask" it.

When a queen requires food, she "asks" for it by stretching out her proboscis toward the mouth of a near-by worker. Owing to age or other cause, this bee may not be prepared to furnish the required food, in which case she turns aside while the queen passes on to one worker after another until she finds one that is prepared to supply her needs. Sometimes she will obtain food from several before her needs are fully met. When prepared to furnish food, the worker, upon being approached by the queen, frequently "offers" her services before being "asked." Or she may wait until the queen stretches out her proboscis before opening her own mandibles to allow the queen to insert her proboscis. Thus the queen takes her food from the "mouth" of a worker in the same manner she or any other bee would sip honey from a cell, or sirup from a dish. In connection with such a transfer of food, the antennae of the queen frequently are brought into contact with those of the worker.

In grooming the queen, the workers "bathe" her by lapping with their tongues, "comb" and massage her with their mandibles, and carry away her feces.

Another activity commonly mentioned is that known as "caressing" the queen. As the queen goes about her duties and especially when she stops to rest or take food, many of the workers close to her reach out to touch or stroke her with their antennae as if expressing affection for her. This probably is not its true significance, but apparently no other explanation has been found.

### Orientation Flights

Short flights in front of the hive and in its vicinity enable bees to become intimately familiar with the appearance of their home and its surroundings. First flights are short and are confined to the immediate vicinity of the hive, but on successive occasions they are increased in duration and scope. Since numerous young bees of a given colony commonly take their first flights together, this activity frequently assumes the appearance of a social occasion to which the term "play flight" often is applied. Such flights are especially noticeable in spring on a warm sunny afternoon following several days of inclement weather. All of a sudden there is a great activity in the air in front of some hive entrance. At first glance one might suspect that a robbing escapade is under way, but closer scrutiny reveals no fighting. Moreover, the bees taking to the air do not fly away as with booty, but join in with the dancing, swaying throng that hovers before the hive. One need not remain long in doubt, however, for so-called play flights are of short duration, seldom lasting more than 5 minutes or thereabouts. They end as abruptly as they start and activity at the front of the hive immediately resumes its normal appearance. At one time or another during the pleasantest part of such a day in spring or summer, similar flights by young bees may be observed in front of practically every hive in the apiary.

### Ventilating the Hive

Bees reduce the temperature within the hive, when it is warm, by using their wings in place of electric fans. And during the honeyflow season, air currents thus set up within the hive hasten the elimination of excess moisture from unripe honey in the open cells. Fanning bees may be observed at their work any day in summer, but especially during late afternoon and early evening on a day when there has been a heavy harvest of nectar (Fig. 49).

The number of fanners varies with the need for forced ventilation, ranging from just a few individuals, when the need is not great, to several hundred bees in extreme cases. Occupying the alighting board, usually for about half the width of the hive but often less, fanners with their heads toward the rear of the hive stand just far enough apart so as not to interfere with each other's movements. By operating their wings vigorously, they set up *outgoing* air currents through their half of the entrance. As the need for ventilation increases, such operations may ex-

tend along the bottom board almost to the rear of the hive. In case of extreme conditions, two batteries of fanners may operate simultaneously, the second group establishing itself on the other side of the bottom board but mostly within the hive, and facing in the opposite direction so that their fanning increases the rate of flow of air passing *into* the hive. This speeds the circulation of air, which enters at one side of the entrance and goes out at the other.

In extremely hot weather, if the bees are unable to ventilate the hive sufficiently to keep the temperature at a comfortable level, they cluster outside on the face and sides of the hive (Fig. 50), as if in an attempt to escape the unbearable heat within. This always is a sign for the beekeeper to provide additional means of ventilation for the colony, generally accomplished by increasing the size of the entrance or by providing an additional one. This also may signify that the colony needs additional super room.

### Guard Duty

According to Rösch (see reference No. 4 in this chapter), guard duty is one of the last activities to be undertaken before field work is begun. The author has observed that the performance of guard duty may be con-

Figure 49. Two purposes of fanning may be observed here. The bees on the alighting board and within the entrance are fanning to ventilate the hive. Those in front of the hive, with their scent glands exposed, are fanning to call other bees to them. (*Photo by F. C. Pellett*)

Figure 50. This colony, as evidenced by the many hundreds of bees clustered on the face and sides of the hive, and even in the grass in front of the entrance, is badly in need of additional means for ventilating in order to cool the interior of the hive. (*Photo by F. C. Pellett*)

tinued to some extent even after a worker has become a fielder. As in human society, guard duty usually is assigned to those in the prime of life and to those physically fit. Rarely do we find either a downy youngster or a decrepit oldster acting as a guard. Bees are adaptable however and, as already mentioned, Haydak (see reference No. 8 in this chapter) found that, in a colony composed of young bees only, workers 3 days old acted as guards. Even 1-day-old bees attempted to attack robbers.

The fact that the honey-bee colony, during the active season, posts guards at every opening that may serve as an approach to its home can be verified by any 10-year-old boy who has succumbed to the temptation to poke a stick into such an opening just to see what would happen. Would-be intruders of all kinds, even bees from a neighboring hive, find themselves challenged upon approaching too near. And lucky is the intruder—regardless of size, unless too minute for bees to notice—who escapes without receiving one or more stings. In case the intruder persists in spite of this warning, the alarm somehow spreads quickly to the rest of the colony and recruits rush to the attack. Every Amazon in the colony, if need be, will join in the fray and without hesitation give her life in defense of the colony. The life of the individual is wholly subordinated to the good of the colony.

### Pollen Packing

The idea that the pollen-packing bee uses her head as a battering ram in the performance of her duty is no longer acceptable. It is now known, and the author's observations verify the fact, that after the twin pellets have been carelessly kicked off into the cell by the fielder, a house bee soon enters the cell and with her mandibles breaks them up. After more or less mandibular manipulation, the purpose of which is not entirely clear, she crowds them against the base of the cell or against other pollen already stored there, as the case may be. She then proceeds to smooth this new material into place with her mandibles.

Exact data are lacking but it may be stated that the amount of time consumed in stowing away a load of pollen is considerably greater than should be required unless one or more functions, other than the mechanical operation of plastering the pollen in place, are involved. That at least one other function is performed during the pollen-packing process seems well founded while a second is not wholly lacking in supporting evidence. Chemical analyses reported by Casteel[22] support the idea that the pollen packer adds honey to the pollen as she packs it. Not only does this result in increasing the nutritive value of "beebread" but it also improves its keeping qualities, for honey is a natural preservative for pollen. And it has been assumed generally that secretions from some of the salivary glands are added also during the packing procedure. This

[22]Casteel, D. B. 1912. The behavior of the honeybee in pollen collecting. *U.S Dept. Agr. Bur. Ent. Bull.* 121.

doubtless could account for the fact that the data referred to suggest that this process may result in an increase in enzymatic action.

### Receiving, Manipulating, and Depositing Nectar

Contrary to oft-repeated statements still to be found occasionally, even in recent publications, the field bee upon entering the hive rarely if ever deposits her load of nectar in the comb, but transfers it to one or more of the house bees. While it seems highly probable that the nectar gatherer upon occasion may deposit her own load in a cell, painstaking observations by the author on thousands of individual fielders, followed continuously from the moment of their arrival at the entrance until their departure for the next load, have failed to reveal a single glimpse of this behavior. Observations reported by Doolittle,[23, 24] Latham,[25] and others are in agreement with the above statements, but Miller[26] was in error when he stated: "The gathering bee . . . puts it directly into the cell."

The unified account of how bees make honey is to be presented later, so a brief summary on the role of the house bee in receiving and manipulating nectar and depositing it in a cell as partially ripened honey will suffice for the present. Upon receiving a load of nectar from a fielder, the house bee proceeds to rid it of part of its excess water by manipulating it with her mouthparts, after which she deposits it in a cell. This is the reason that nectar when first deposited in the comb is already considerably more concentrated than when gathered from the flowers.

## Working Habits of Field Bees

Activities involving flight sometimes begin as early as the third or fourth day, but normally few foraging trips are made under the age of about 3 weeks. Trips made prior to this time, in the main, are orientation flights during which the young bee on successive occasions ventures farther and farther from home, exploring first the immediate surroundings of the hive itself and later the fields over which she will need to find her way home, after assuming the duties of a forager. Thus orientation flights gradually lead to and culminate in the shift from indoor to field duties at the age of about 3 weeks, or a trifle less.

### Sequence of Field Duties

The order, if any, in which the several field duties are undertaken by the individual has not been determined with certainty. Wiltse (see refer-

---

[23] Doolittle, G. M. 1890. Bees unloading the honey. *Amer. Bee Jour.* **30**:503.

[24] Doolittle, G. M. 1907. Where do the field-bees deposit their loads? *Amer. Bee Jour.* **47**:653-654.

[25] Latham, Allen. 1907. Where do the bees deposit their loads of nectar? *Amer. Bee Jour.* **47**:716-717.

[26] Miller, Arthur C. 1907. Observing the home life and habits of the bee. *Amer. Beekeeper* **17**:42-44.

ence No. 9 in this chapter), in 1882, observed the activities indulged in from day to day by a small colony composed solely of newly emerged workers. Obviously his observations were made under abnormal conditions and, therefore, his findings cannot be accepted as representing activities of a normal colony. But in the absence of conclusive data they are not totally devoid of interest. As individuals were not marked, these data do not show whether or not there was any correlation between age and duty performed.

According to Wiltse's report, first trips for water, nectar, and pollen were made in the order here named, and occurred on the fourth, sixth, and eleventh day, respectively. On the seventh day, several hundred bees gathered nectar and several cells were partly filled that day. When, in spite of the presence of uncapped brood, no pollen had been brought in by the morning of the eighth day, the bees were transferred to combs that were empty except for several square inches of open brood and five cells partly filled with honey, but containing no pollen. By the tenth day, about 2 pounds of honey had been stored but still no pollen, and no bees had been seen to enter the hive with any. Finally, during the forenoon of the eleventh day, one lone load of pollen was brought in—presumably the very first one, and by the end of the twelfth day several cells had been partly filled with pollen. Inasmuch as the honeyflow was not so good after the tenth day, Wiltse concluded that, if nectar had been scarcer, the bees might have gathered pollen sooner.

Nelson (see reference No. 10 in this chapter), who likewise made observations on colonies composed of young bees only, thought that some of the first loads were water but he could not be sure. In one experiment he found that nectar was brought in on the sixth day whereas no pollen was carried until the tenth day. In another experiment the first nectar was brought in on the seventh day and the first pollen on the eighth.

As indicated earlier, Rösch failed to find any definite sequence for duties performed outside the hive. Studies by the author, to be reported in subsequent pages, lend support to a growing conviction among students of bee behavior that the duty performed by a fielder probably depends far less on age than upon circumstances.

## Fidelity to Occupation

The best-known studies on the constancy of the field bee to her particular line of work were made by Bonnier,[27] a botanist and beekeeper of France, who used different colors to mark individuals engaged in the several types of field work. Various attempts were made to get nectar carriers to accept pollen and pollen carriers to take nectar, but without success. Of the marked bees engaged in carrying water, nectar, pollen, or propolis,

[27] Bonnier, Gaston. 1906. Sur la division du travail chez les abeilles. *Comptes Rendus de l'Acad. des Sci.* **143**:941-946.

each remained constant to her special duty and could not be induced to desist, even to collect honey placed before her.

Some years ago the author made studies on various activities of hundreds of marked individuals. Particular care was used to observe bees working under normal conditions at their duties during periods of from 5 to 10 days, and occasionally longer. It was found that marked fielders engaged in carrying water, nectar, or pollen continued their respective kinds of work for days together. In the light of the generally accepted age theory, it was a little surprising to find that in a few instances only did any marked forager change her occupation during a period of observation.

Some nectar carriers and pollen carriers occasionally were found to cease their field labors for a part of a day, and then resume their accustomed work the following day. Whether such bees busied themselves with work inside the hive on such occasions was not learned, but usually it was not difficult to discover a satisfactory reason for the temporary discontinuance of their foraging trips. During any portion of a day when no nectar was available from the particular kind of flower from which a given bee had been gathering, that bee seldom went to the field even though nectar could have been secured from other kinds of flowers. And a bee accustomed to carrying pollen from a plant such as corn, which produces no nectar, rarely was found to leave the hive after her particular kind of pollen ceased to be available for the remainder of the day. Thus it was found that for days together a field bee remains faithful to her occupation.

## Fidelity to Plant Species

Centuries ago Aristotle noted that on any one trip a honey bee confines her visits to the flowers of a single species. Subsequent observers have continued to study this interesting trait which is of utmost economic importance to agriculture because of the indispensable role of the honey bee as chief pollinator of many orchard, garden, and farm crops. While it is recognized that honey bees occasionally lapse in their fidelity to species, they usually do so to such a minor extent[28, 29] and under such circumstances as not to detract materially from their efficiency as cross-pollinators. Lapses in constancy are not uncommon in gardens where various species are represented by relatively few plants, but in fields and orchards where crops are dependent upon bees for cross-pollination, their fidelity is all but perfect. Aside from certain insects that confine their visits to a single species, no other insect is more constant than the honey bee.

## Visits Restricted to Limited Area

Foragers fly but short distances when going from blossom to blossom unless disturbed, or unless flowers of the species sought are scarce. Fur-

[28]Betts, Annie D. 1920. The constancy of the pollen-collecting bee. *Bee World* 2:10-11.
[29]Betts, Annie D. 1926. The honeybee and flower evolution. *Bee World* 8:50-52.

thermore, it has been found that there is a strong tendency for individuals to restrict their labors to a certain limited portion of a field or garden. Bonnier one day marked all bees working on a 3- by 16-foot strip of buckwheat (*Fagopyrum esculentum*) and the next day found only marked bees there. From field studies on the area ranged over by the individual foragers working on dandelion, clover, and various cultivated plants, Minderhoud[30] found that, where blossoms of the species sought are plentiful, the foraging bee confines her visits to a fixed area, seldom greater than about 10 yards square.

Other valuable studies along this line have been reported recently by Butler, Jeffree, and Kalmus[31] who used both natural and artificial sources of supply. More than a hundred feeders filled with sugar sirup were arranged at intervals of about 20 yards in both directions from each other in a meadow near the apiary. Individual bees showed a high degree of constancy to a given feeder but, if the supply became exhausted, would stray to another near-by feeder. After that the forager would visit either the old or the new source, or both, when sirup was replenished at the original source. Bees marked while working willow herb (*Epilobium angustifolium*) situated in the midst of a large field of this species usually were recovered within 5 yards of the point of marking. Such bees remained "fixed" to this area for several days. Bees marked on isolated patches of globe thistle (*Echinops sphaerocephalus*) continued to visit the same patch for periods up to 16 days. The percentage that strayed to other patches of the same species 18 yards away was about 10 per cent each day.

### *Constancy to a Single Bush*

The trait of fidelity in the foraging bee carries yet deeper than to species and area. Buzzard[32] has shown that in the case of sizable bushes, such as those of *Cotoneaster horizontalis* which bear an abundance of flowers, this trait extends even to individual plants. On a day early in May he marked a dozen bees among the hundred or more observed at work on each of three bushes of this species. Each bush was about 1 foot in height and covered an area approximately 2 yards square. He used red, blue, and yellow colors for marking bees found on the respective bushes. During the next 5 days he made an average of three observations each day and found that the same marked bees persistently returned to the very same bush upon which each was first observed, and strayed from one bush to another only where the branches intertwined. Only three instances of straying were observed, and in each case the forager returned to her own bush almost immediately.

---

[30]Minderhoud, A. 1931. Untersuchungen ueber das Betragen der Honigbiene als Blütenbestäuberin. *Gartenbauwissenschaft* **4**:342-462.

[31]Butler, C. G., E. P. Jeffree, and H. Kalmus. 1943. The behavior of honeybees on an artificial and on a natural crop. *Jour. Exp. Biol.* **20**:65-73.

[32]Buzzard, C. N. 1936. De l'organisation du travail chez les abeilles. *Bull. Soc. Apicult. Alpes-Marit.* **15**:65-70.

From observations on bees working on smaller plants, such as globe thistle and willow herb, Butler[33] states that a bee working on a group of plants (her fixation area) almost always alights on one particular plant when arriving from the hive, and comes back to it when ready to take off for home. Others who have studied the working habits of field bees agree that foragers usually restrict their visits to limited areas, and frequently show great constancy to a single bush or other well-defined group of flowers. Thus no time is wasted in unprofitable flight between flowers, with the result that the utmost in harvesting is accomplished with the least possible expenditure of time and effort.

### Distribution of Foragers

According to Bonnier, whose studies on the activities of marked foragers have been cited already, field bees may be divided into searchers and collectors. Searchers act as scouts, seeking sources of pollen and nectar. When a suitable source is found and other bees come to it, they all become collectors, including the searcher. During a good honeyflow, searchers go out only in the early morning and soon all become collectors, but during a dearth searchers are out all day. It seems probable that we have here a plausible explanation of why robbing tendencies are lacking during a good honeyflow and so severe during a dearth.

Bonnier observed also that only a sufficient number of collectors came to a given group of flowers to gather the available nectar or pollen, as the case might be. When he doubled the number of flowers, additional workers appeared until their number was approximately twice what it was before. After that no additional recruits joined in collecting although an occasional unmarked bee (a searcher) would pause to evaluate the situation and then fly away. Bonnier concluded that, unless disturbed by the arrival of numerous other Hymenoptera, the number of foragers working on a flower species varies directly with the number of flowers.

Butler *et al.* (see reference No. 31 in this chapter) found that, when feeders containing sugar sirup were placed at distances ranging from 160 to 400 yards from the apiary, there were always more visitors to the nearer than to the more distant feeders. Bees working on the farthest feeders, however, did not change to those nearer home when the weather became unfavorable. But there was some evidence to indicate that bees working a long way from the hive were more easily deterred from foraging by unfavorable weather than were those working close to the apiary. Behavior of bees working on feeders is not, however, a wholly reliable guide to their behavior on natural sources of nectar. The tendency for foragers to overcrowd flowers located near their hives is all but nonexistent, but that is not to say that bees will be found in as great numbers on blossoms at a distance as on those nearer home.

---

[33]Butler, C. G. 1945. Effects of nectar abundance and concentration on bee activity. *Jour. Exp. Biol.* 21:5-12.

## Communication Among Bees

Communication by means of sounds, as we perceive them, has never been proved for bees although there is considerable evidence to indicate that certain sounds or vibrations are significant to them. Another supposed means of communication is by touch, such as may be observed when two bees meet and stroke each other's antennae. Sladen's work,[34] in 1901, showed that bees call their hivemates to them by the emission of a peculiar odor from a gland located between the sixth and seventh dorsal segments of the abdomen. But, why do bees of a colony rush forth so frantically when, during a dearth, a robber bee has returned home with her plunder? And how do bees communicate to each other that they have found a source of food supply, in order that the colony may take full advantage of its opportunity to store in abundance?

Bonnier (see reference No. 27 in this chapter) observed but was unable to explain the fact that, when the number of flowers was increased, additional collectors came; whereas, when the number of flowers was reduced, fewer collectors appeared at the flowers. And no satisfactory explanation was forthcoming until 1920, when Frisch[35] published his work on *The Language of Bees*. Observations and experiments carried on during 1919 and 1920, without any knowledge of Frisch's work, enabled the author[36, 37] to confirm his conclusion that the "dance" performed at times by loaded fielders just returned to the hive is a means employed to inform other bees that food is to be had for the getting.

Of course such a striking activity must have been noticed by untold numbers of people, and doubtless its meaning has been surmised independently by a number of unknown observers. As a matter of fact, this "dance" was noted and given essentially its correct interpretation by Spitzner,[38] as long ago as 1788, and was carefully described, in 1823, by Unhoch.[39] But, like many other bits of information, these observations published so long ago had been forgotten and have been rediscovered from time to time without knowledge of previous discovery. And this process still is going on. In 1886, Root[40] suggested the essence of the true meaning of the "dance" at a time when the usual interpretation was that this behavior was restricted to young bees bringing in their first loads.

---

[34]Sladen, F. W. L. 1901. A scent-producing organ in the abdomen of the bee. *Gleanings in Bee Culture* 29:639-640.

[35]Frisch, K. v. 1920. Ueber die "Sprache" der Bienen. *Munch. Med. Wochenschr.* pp. 566-569.

[36]Park, Wallace (O. W.). 1923. The "language" of bees. *Bee World* 5:3.

[37]Park, Wallace (O. W.). 1923. Some "whys" of bee behavior. *Amer. Bee Jour.* 63: 399-400.

[38]Spitzner, M. J. E. 1788. *Ausführliche Beschreibung der Korbbienenzucht im Sächsischen Churkreise, ihrer Dauer und ihres Nutzens, ohne künstliche Vermehrung nach den Gründen der Naturgeschichte und nach eigener langer Erfahrung.* 466 pp. Leipzig.

[39]Unhoch, Nicolaus. 1823. *Anleitung zur wahren Kenntnis und zweckmässigen Behandlung der Bienen.* 246 pp. Munchen.

[40]Root, E. R. 1886. Juvenile department. *Gleanings in Bee Culture* 14:666-667.

To Frisch, however, must go the credit for having demonstrated by numerous careful experiments that the "dance" of incoming foragers is a means of communicating to their hivemates certain information concerning available booty.

From his earlier work, Frisch (1920) erroneously concluded that nectar carriers perform a "round" dance, while pollen gatherers do quite a different "tail-wag" dance. In his recent work, however, Frisch[41] frankly acknowledges this to be a mistake, and substantiates the author (see reference No. 44 in this chapter) who, in 1923, observed: "Bees in this country may be out of date, for they still adhere to the old-time 'wag' or 'tail dance,' regardless of whether they carry nectar, pollen, or water."

On the basis of his recent studies, Frisch reports that the kind of dance performed by an incoming forager is determined not by the character of her load, but by the distance of the food source from the hive. When the source is less than about 75 yards (50 to 100 meters) away, she does the round dance, during which she moves in a complete circle, then turns and describes one in the opposite direction. But when the distance is greater than about 75 yards, the forager performs a wag-tail dance in which she dances around a semicircle, then runs straight along the diameter, wagging her tail as she goes. She then turns and dances around the other half of the circle and repeats—the number of repetitions depending upon the distance to the source of the supply. If only a little over 75 yards away, there may be as many as 40 wag-tail runs in a minute, but their number decreases with increased distance, until at 2 miles only about eight tail-wagging runs are performed per minute.

Furthermore, the direction of the food supply from the hive was found to be indicated by the direction of the straight portion of the forager's run. By a vertical upward run, the dancer indicates that the feeding place is in the same direction as the sun, or by running downward she shows it to be in the opposite direction. To indicate a location to the right or left of the sun, she runs upward and to the right or left of the vertical at an angle equal to that by which the source of supply lies to the right or left of the sun, as the case may be.

Thus, when a forager finds an abundant source of supply she reports her discovery, upon returning to the hive with a load, by performing one of the recruiting dances described above. The plant species from which her load was obtained is indicated both by the flower scent adhering to her body and by the odor of her load. As a result of this performance, bees so informed leave the hive in search of flowers having the odor carried by the dancer. The direction and approximate distance having been learned from the type and vigor of the dance, the recruits usually are able to locate the source without difficulty. Upon returning with loads, they in like manner perform the dance.

[41]Frisch, Karl v. 1946. Die "Sprache" der Bienen und ihre Nutzenwendung in der Landwirtschaft. A 21-page reprint from *Experientia*, vol. 2, No. 10.

As long as the supply continues abundant, most of the returning bees perform the dance, thereby sending recruits to the field in ever-increasing numbers. But as soon as the supply becomes depleted, the returning foragers cease to perform the dance, and in many cases do not themselves return to the source until some searcher, finding the supply renewed, returns with a load and performs the dance, again starting waves of foragers to the field. Here then we have an explanation for Bonnier's observation that the number of collectors varies directly with the abundance of the supply.

### Speed in Flight

Fantastic estimates of the speed of the bee in flight have been given by various authors. Some of these estimates run as high as 120 miles per hour but several, based upon more or less careful observations, have been placed at 30 miles per hour, and even less. To secure more definite information about the speed of the bee in flight and to study the reactions of the bee to the influence of wind, experiments were carried out at the Iowa Agricultural Experiment Station by the author.[42]

#### *Influence of Wind*

In accordance with one of Nature's laws, a bee traveling with the wind is assisted in its flight to the extent of the velocity of the wind; in traveling against the wind, the bee's progress is hindered to the extent of the wind's velocity. If the bee flies at an angle to the wind, its rate of progress will be the resultant determined by triangulation. Thus, a bee that has flown due south at an observed velocity of 12 miles per hour, while a wind having a velocity of 9 miles per hour was blowing from the west, would have flown at the rate of 15 miles per hour, instead of 12, had there been no wind blowing.

When flying at right angles to the wind, the bee must hold itself at an angle to the line of flight, flying against the wind just enough to offset that force, which otherwise would carry the bee away from its line of flight. In the case above, the rate of flight was reduced 3 miles per hour by the 9-mile wind. Thus, it will be seen that wind blowing at right angles to the line of flight has the same effect as a somewhat lesser wind blowing directly against the bee. Then, the fair way to compute the normal speed of flight is to reduce all results to terms of calm. Unless otherwise stated, all speeds mentioned hereafter have been reduced to terms of calm.

#### *Speed of Flight in Terms of Calm*

The average speed for loaded bees varied only a little, from 13 to 16 miles per hour, while the average was approximately 15 miles per hour. The average speed of *empty* bees varied from 6.8 to 18 miles per hour, while the average was 12.5, or 2.5 miles per hour less than that for the

[42]Park, Wallace (O. W.). 1923. Flight studies of the honeybee. *Amer. Bee Jour.* 63:71.

homeward-bound bees. This suggests the possibility that a bee on her outward journey may not in all cases make a so-called "bee line" for the source of supply, but may sometimes do more or less scouting on the way. It is significant that, when flying at right angles to the wind, the outgoing bee flew at the rate of 13.3, and the incoming bee 14.6 miles per hour, because each approaches rather closely the general average of its respective class. Furthermore, in spite of the heavier load, the homeward journey usually was accomplished in less time than the outward one. The only case in which the outgoing bee made better time than the incoming one was when flying directly against the wind.

The least speed was shown when flying with the wind, on both outward and homeward trips; the greatest speed in each case was attained when flying directly against the wind. It appeared that, when going with the wind, the bee showed a tendency to slacken her own efforts; whereas, when traveling against the wind, she increased them in an attempt to overcome the wind's retarding influence.

A maximum of approximately 25.5 miles per hour was recorded for both outgoing and incoming bees, but they did not long continue to work in a wind blowing much over 15 miles per hour. Temperatures were relatively high during these experiments, being between 70° and 80° F. No relationship between temperature and rate of flight was apparent, but a wider temperature range might yield a correlation.

## Activities of Water Carriers

Water has various uses in the beehive, some of which are highly essential. Water is required by the nurse bees whenever it becomes necessary to thin down ripe honey in the elaboration of larval food. When fresh nectar is available, it usually can be used in the preparation of brood food without dilution. Hence we find that the activity of water carriers is most noticeable in early spring before the honeyflow begins, and that it practically ceases when nectar is coming into the hive in abundance, unless the nectar is highly concentrated.

It often has been observed that, in cool weather, water carriers seek a sunny spot where they can suck water from moist earth in preference to the large open reservoirs (Fig. 51) which they seem to choose in hot dry weather. This is in accord with results obtained by Gendot[43] who undertook to discover why bees at times seem to prefer to collect water from compost heaps. Finding that water in the puddles near a compost heap had a higher temperature than the surrounding air, he set out two containers one of which was warmed with an alcohol lamp. He found that water carriers showed a 6-to-1 preference for water warmer than cool April air, but when warm weather prevailed they took from one reservoir as readily as from the other. He further found that, within the range of 50°

[43]Gendot, Georges. 1907. Eau necessaire aux abeilles. *L'Apiculteur* 51:164-168.

FIGURE 51. Water carriers obtaining their loads at a watering place. (*Photo by Chas. B. Tator*)

to 110° F., the rate at which a bee takes up a load of water is directly proportional to the temperature of the water.

The extent to which water is needed by adult bees has not been determined. Bees normally do not store up water in their combs and yet, in winter when no brood is present, they are able to survive long periods of confinement without access to water. These facts have led many to assume that water is not needed by adult bees. On the other hand, workers caged either on candy or on ripe honey often take water with avidity when it is offered and live longer than do those that lack it. And although bees are unable to utilize honey (or other sugar) in the granulated form, when conditions permit, they often liquefy such granules by adding water. In hot dry climates, water carriers renew their activity whenever necessity demands the use of water within the hive for reducing excessive temperatures through evaporation, and for humidifying the air sufficiently to prevent undue drying of the larvae.

## BEHAVIOR OF WATER CARRIERS

On the first good flight day after a 45-day confinement in the early winter of 1918, bees were found returning to a one-frame observation hive carrying large loads. Two dozen of them were caught as they entered the hive and, by putting them to the filter-paper test,* were found to be car-

*The author has found that a water carrier may be distinguished from a nectar carrier by pressing gently on the abdomen of the loaded bee while she is held fast on a sheet of filter paper. If the disgorged honey-sack content is nectar, a translucent spot will be produced on the filter paper; whereas, if it is only water, no such spot will remain upon drying. *See*: Park, O. W. 1926. Water carriers versus nectar carriers. *Jour. Econ. Ent.* 19:656-664.

rying water. The water carriers hustled through the glass-covered tunnel and into the hive with a decidedly businesslike air, and climbed upon the comb where they began at once to shake their abdomens vigorously from side to side, all the while running in arcs of circles, turning alternately to the right and then to the left.

Other workers, attracted by the behavior of one of these dancing water carriers, would attempt to approach her. Usually there were from one to four or five bees following each dancer, and at more or less frequent intervals the dancer paused long enough to pass out a sip of water to one of the near-by workers. An occasional bee obtained a long draught. Sometimes the recipient was one that had been following, but frequently it was some other bee which apparently had shown little or no interest.

At times, a water carrier will dance for a full minute before offering to give up her load. Again, a water carrier enters and performs a brief dance; then proceeds rapidly to dispose of her load to this bee and that as she, figuratively, elbows her way through the crowd with the same businesslike attitude with which she entered the hive. Sometimes she gives a small sip to each of a half-dozen bees in quick succession before resuming her dance, and then, after dancing awhile, transfers the balance of her load to one or two bees. It is not unusual to see two or three bees being supplied all at one time by a single water carrier. In some instances, the entire load is disposed of to two or three individuals, while in other cases a single load is distributed among as many as 18 workers.

Having disposed of her load, she begins preparation for her next field trip by securing a small amount of food from one or more of the house bees; or, failing in that, she goes to a cell and takes a sip of honey. It is not unusual for her to meander over the comb for a minute or more, but more often she starts at once for the field. But, before making the final start, she almost invariably gives her tongue a swipe between her front feet, rubs her eyes, and often cleans her antennae. Then with a quick look around as if taking her bearings, she sets off for the exit in great haste. These preparations and the quick start are so characteristic that an observer soon is able to tell whether a bee is starting for the field, or whether she is just going to another part of the hive.

As the dancer proceeds with her maneuvers, every now and then, one of the interested followers may be seen to leave for the field, until by the time the dancer has disposed of her load, a dozen or more may have departed for the field to search out the source of supply. Sometimes these bees obtain a little food from other bees or from cells of honey before leaving. Upon their return with loads of water they also perform the dance. Thus, the dance is employed as a means of communicating to their hivemates that a plentiful supply of water is available. Information relative to direction and distance to the source of supply may be communicated also by means of the recruiting dance (see "Communication Among Bees" in this chapter).

Dancing water carriers are to be found in almost any colony on a flight day in winter or early spring following a period of confinement. As far as is known, no mention of the dance of water carriers appears in bee literature prior to the first publication[44] of these observations in 1923.

### Storage of Water by Bees

It can no longer be doubted that in hot dry climates, at least, bees sometimes deposit water within the hive. Testimony to this effect by such competent observers as Chadwick,[45] Small,[46] Rayment,[47] and Parks[48] are not to be ignored. It is to be noted that all of these observers have been located in regions where hot dry weather is prevalent, and water was observed in the hive only during hot drouthy weather. The fact that earlier observers failed to discover water deposited in combs only shows that such an occurrence was rare under the atmospheric conditions under which they lived and made their observations.

The following description of where bees deposit water is quoted from Prof. H. B. Parks, for many years Chief of the Texas Apicultural Research Station near San Antonio, Texas:

> To those who have never visited this section of the world the storage of water within the hive may seem quite curious and a description of where water is stored is therefore given. Every beekeeper has noted the presence of small cell-like enclosures on the top bars, generally made of old wax and propolis. These same cavities are found on the upper surfaces of all the brood combs and brace combs in the hive. In the district of which I write and during the hot period of summer if you will remove the cover from the hive the first thing that will attract the attention is the presence of water in considerable quantity in each one of these cell-like structures on the top bars. Very often it is in sufficient quantity that drops of the water will run from the comb that is tilted. Removing the frame, especially one which contains a great deal of sealed brood, every indentation in the capping will be found to contain a small amount of water. In fact, the comb looks as if it has been sprinkled and that droplets had spread out in the cavities over the points where the hexagons meet. All beekeepers have noted that the capping of brood is very soft and spongy, and here, during hot months this spongy capping material will be found saturated with water. Removing combs from the sides of the brood nest a considerable circle of what appears to be fresh nectar will be found in several of the side combs. This supposed nectar proves to be water.

Chadwick advances the very plausible theory that the water is employed for the cooling effect derived from its evaporation, and both Small and Parks support this theory, adding the opinion that a certain degree of humidity is necessary to keep the larvae from drying up. It is to be assumed that the bees use some small part of this water in the prepara-

---

[44]Park, Wallace (O. W.). 1923. Behavior of water carriers. *Amer. Bee Jour.* **63**:553.
[45]Chadwick, C. P. 1922. Ventilation. *Amer. Bee Jour.* **62**:158-159.
[46]Small, A. V. 1922. Water in cells. *Amer. Bee Jour.* **62**:272.
[47]Rayment, Tarlton. 1923. Through Australian eyes.—Water in cells. *Amer. Bee Jour.* **63**:135-136.
[48]Parks, H. B. 1929. Water storage by bees. *Iowa State Apiarist Rpt.* **1928**: 53-56.

tion of pap for the brood, but according to Chadwick, "The quantity of water used by the colony of bees for the purpose of ventilation exceeds that used for all other purposes, many times."

Most of the observers indicate the top bars and upper part of the hive as the principal region of deposit. It seems clear, therefore, that bees make use of the well-known principle employed in locating the cooling element at the top of iceboxes and refrigerators. The air there, being cooled, becomes denser and sinks toward the bottom, thereby cooling the entire chamber and automatically humidifying it at the same time. Thus it would appear that these accomplishments of the honey bee antedate those of our human engineers by some millions of years.

It is to be noted, however, that even in such cases as mentioned by these observers there is no storage of water in the same sense that honey and pollen are stored, as a carry-over for the period when additional supplies cannot be obtained. On the other hand, water so deposited apparently is intended only for immediate use in the regulation of temperature and humidity in the hive.

In most localities there nevertheless appears to be an actual need for some means whereby the bees can store a supply of water sufficient to last the colony from one flight day to the next during the early spring brood-rearing period. Observations and experiments to determine how the bees meet this need were made some years ago at the Iowa Experiment Station.[49]

Outside of the tropics, bees are able to obtain water for brood rearing only on occasional warm days during early spring. Observations showed that at such times the bees brought in more water than was required for one day. On the first flight day following a period of confinement, bees carried water feverishly, but they carried little or none the next day, even though the day was equally pleasant and water readily accessible. Inasmuch as careful examination of the combs failed to reveal water deposited in them, the natural conclusion was that the water carriers did not deposit their loads in the comb, but either retained them or transferred them to other bees.

Using a one-frame observation hive, it was found that, on such occasions, the water was stored in the honey sacks of numerous bees of the colony. As the water was transferred, the abdomen of the water carrier decreased in size while that of the "reservoir-bee" became distended. It seems strange that this method of storing water should have escaped the notice of others, but no prior reference to it is known in bee literature. A somewhat similar activity, however, is known in the case of the honey ant, in which certain workers having enlarged abdomens serve as storage vats for honeydew which others collect. And, according to Comstock,[50]

---

[49]Park, Wallace (O. W.). 1923. Water stored by bees. *Amer. Bee Jour.* 63:348-349.

[50]Comstock, J. H. 1936. *An Introduction to Entomology.* pp. 947-948. Ithaca, N. Y. Comstock Publishing Co.

"When the season for obtaining honeydew is past, these living cells disgorge their supply through their mouths, for the use of the colony."

The reservoir-bees were quite inactive and occupied places surrounding the brood area, rather than within it. When a good flight day was followed by a period of several days without access to more water, the abdomens of these reservoir-bees became greatly reduced in size. Then, on the first subsequent flight day, it became evident that they were being refilled.

On several occasions, an observation colony was fed water that had been colored with a harmless and tasteless dye, so that the water was easily distinguished through the semitransparent abdomen of any bee that obtained it. The feeder was so placed that it was possible to mark every bee that took a load of water. Rarely did an unmarked bee appear at the water pan, but those already marked made repeated trips for more water. By evening, several hundred unmarked bees showed the presence of large loads of colored water. Tests revealed that these "reservoirs" were filled almost entirely with water. The following morning it was found that about 1300 bees, or half the colony, were acting as reservoirs. The increase in the number of reservoir-bees which mysteriously appeared overnight was readily explained, however, when tests were made on these individuals. Of 31 bees tested, the majority contained honey somewhat diluted. Thus it was found that, in storing water to last from one flight day to another in spring, the bees did not keep the water by itself longer than a few hours, but combined it with honey. A small amount of this diluted honey sometimes was deposited* in or near the brood area, but most of it was retained in the honey sacks of numerous reservoir-bees.

The amount of water that can be stored in this manner is quite limited, especially in a small colony. But during the early part of the brood-rearing period the quantity of water required is not large and, as brood rearing increases, flight days come more frequently. It has often been noticed that brood rearing tends to slacken during protracted spells of cool weather in spring, and it is thought that the inability of bees to store a sufficient water supply is one of the important causes.

So, in conclusion, under hot dry conditions, bees deposit water in the hive to regulate temperature and doubtless humidity; under normal conditions in temperate climates, they store water by combining it with honey in the honey sacks of numerous reservoir-bees. This mixture may then be deposited in the combs or retained until used.

## Time Factors

Time records[51] on trips made by marked water carriers were secured in 1921. Very little brood was being reared and the weather was excep-

*This behavior explains most of those puzzling instances in which the beekeeper, in early spring, finds what appears to be new honey recently deposited in cells within or near the brood nest, when he knows well enough that nectar is not yet available.

[51]Park, O. W. 1928. Time factors in relation to the acquisition of food by the honeybee. *Iowa Agr. Exp. Sta. Res. Bull.* **108**.

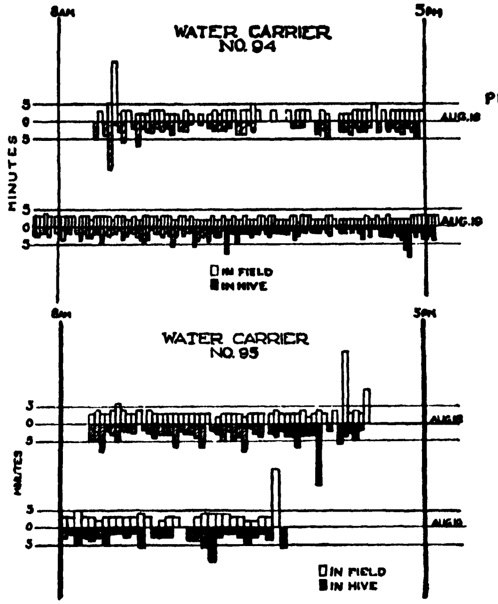



FIGURE 52. Illustrating the workday of two individual water carriers on two consecutive days in August when the weather was exceptionally cool. (*Graph by the author*)

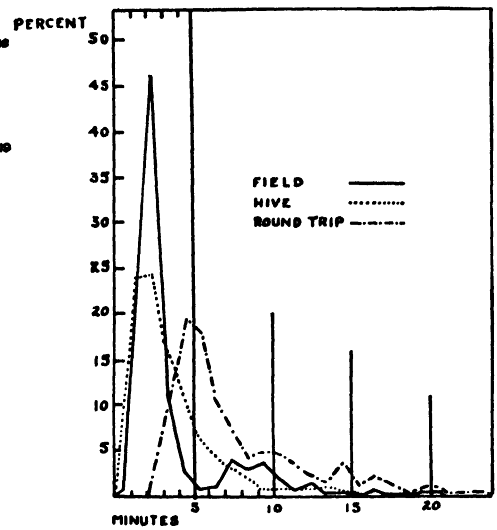



FIGURE 53. Frequency distribution of time records for field trips, hive stays, and round trips made by water carriers. (*Graph by the author*)

tionally cool for August, so the data secured can scarcely be representative of the average number of trips per day. The results for the average time spent in making field trips, however, probably are not very different from those which might be obtained under conditions which would induce water carriers to work longer hours.

The mean time per trip varied considerably. One bee, which averaged about 15 minutes per round trip, was found to be going two-thirds of a mile to get salt water, instead of taking the brook water at the edge of the apiary where it was presumed that most of them availed themselves of the abundant supply near at hand. This seemed quite certain in the cases of those bees which seldom were gone from the hive more than 3 minutes at a time (Fig. 52). A bee commonly spends a minute or more in taking up a load of water, and it takes 1 minute for the bee to fly a quarter of a mile. An occasional long trip outweighs a number of short ones in determining the mean, so all records have been arranged according to their frequency distribution (Fig. 53).

Of all recorded field trips, 67 per cent were completed in 3 minutes or less, and 92 per cent in 10 minutes or less. The time spent in the hive was 2 to 3 minutes, as a rule, and seldom did one remain as long as 5 minutes. Minderhoud[52] gives time records for the trips made in 1 day by four

[52]Minderhoud, Anton. 1929. *Onderzoekingen over de mijze waarop de honigbij haar voedsel verzamelt.* 94 pp. Wageningen. H. Veeman & Zonen.

marked water carriers; averages for the duration of field trips, hive stays, and round trips correspond closely with those given above.

In conclusion, it may be stated that a water carrier can make a round trip in 5 minutes when the supply is near at hand. Sometimes 100 or more trips are made in a day by a single water carrier, but the average probably is nearer half this number.

### Labor Factors

The weight of water a bee can carry at one load has not been determined. But knowing that a given volume of water weighs only two-thirds that of an equal volume of honey, and that a worker can carry about 75 milligrams of honey, then a maximum load of water would be in the neighborhood of 50 milligrams, and ordinary loads about 25 milligrams.[53] The average amount of water brought into the hive in a day by one bee making 50 trips and carrying 25 milligrams at a load would total about 1/400 of a pound. Thus about 400 water carriers would be required to bring in daily a pound (or a pint) of water.

During the inclement weather of early spring, it often is imperative for each colony to bring in and store during a single day all the water it is possible for its reservoir-bees to hold. By this means only is the colony able to maintain the water supply that is so essential to brood rearing. Hence the working force employed in carrying water may involve hundreds of individuals. Data secured in May, 1920, following a 1-day period of confinement, showed that between 6:30 and 11:15 a.m. three colonies on scales carried water to the extent of 3, 4, and 8 ounces. At this rate, the amounts would average 10 ounces, or two-thirds of a pint, for the whole day, with a maximum of a full pint for the strongest colony.

Gendot (see reference No. 43) reports that 12 colonies took one-third of a pint per colony each day from two reservoirs; the maximum for 1 day was nearly a pint per colony. Rayment (see reference No. 47) reports a case in which 150 colonies in a desert situation in Australia regularly used up a little less than a pint per colony each day.

It would appear, therefore, that the daily water requirement for an average colony during spring brood rearing probably ranges in the neighborhood of a third of a pint under average conditions. For strong colonies, and especially under hot drouthy conditions, it must sometimes amount to well over a pint, if not indeed several pints per day.

## Activities in Gathering and Storing Pollen

The well-being of the honey-bee colony during the brood-rearing season is as dependent upon pollen as it is upon honey. Pollen is practically the sole source of protein in the food of the larval bee. Without pollen,

[53]Park, Wallace (O. W.). 1925. Field bees and their work. *Rpt. 7th Internatl. Cong. of Beekeepers, Quebec, Sept. 1924.* pp. 472-478.

brood rearing is all but impossible, and the amount of brood that can be reared without it is inconsequential from a practical standpoint. The extent to which pollen is used by adult bees for purposes other than the elaboration of larval food has not been determined. It is known, however, that a prosperous colony will bring in about 75 pounds of pollen during the course of a season.

## Behavior of Pollen Gatherers

The following description of the manipulation of pollen from the time it is taken from the flower by a bee until it is stored within a cell in the comb is a summary of a comprehensive description presented by Casteel (see reference No. 22 in this chapter). For identification of the leg parts mentioned below, the reader is asked to refer to Chapter XIX, "The Anatomy of the Honey Bee."

Describing bees collecting from sweet corn, which yields pollen in abundance, Casteel states that the bee alights on a tassel and crawls along the spike, clinging to the pendent anthers. The tongue and mandibles are used in licking and biting the anthers, with the result that pollen grains stick to the mouthparts and become moistened with honey and saliva. Also, a considerable amount of pollen is dislodged from the anthers, and adheres to the hairy legs and body. The branched hairs of the bee are suited to retaining the pollen which is dry and powdery.

After the bee has crawled over a few flowers, she begins to brush the pollen from her head, body, and foreward appendages and to transfer it to the posterior pair of legs (Fig. 54, left). This may be accomplished while she is resting on the flower, but more often while she hovers in the air before seeking additional pollen. The wet pollen is removed from the mouthparts by the fore legs. The dry pollen clinging to the hairs of the head region also is removed by the fore legs, and added to the pollen moistened by the mouth.

FIGURE 54. A flying bee (at left), showing the manner in which the fore legs and the middle legs manipulate pollen. The fore legs are removing pollen from the mouthparts and face. The middle leg of the right side is transferring the pollen upon its brush to the pollen combs of the left hind planta (basitarsus). A small amount of pollen has already been placed in the baskets.

A bee on the wing (center), showing the position of the middle legs when they touch and pat down the pollen masses. A very slight amount of pollen reaches the corbiculae through this movement.

A bee on the wing (at right), showing the manner in which the hind legs are held during the basket-loading process. Pollen is being scraped by the pecten spines of the right leg from the pollen combs of the left hind planta (basitarsus). (*Drawings after Casteel*)

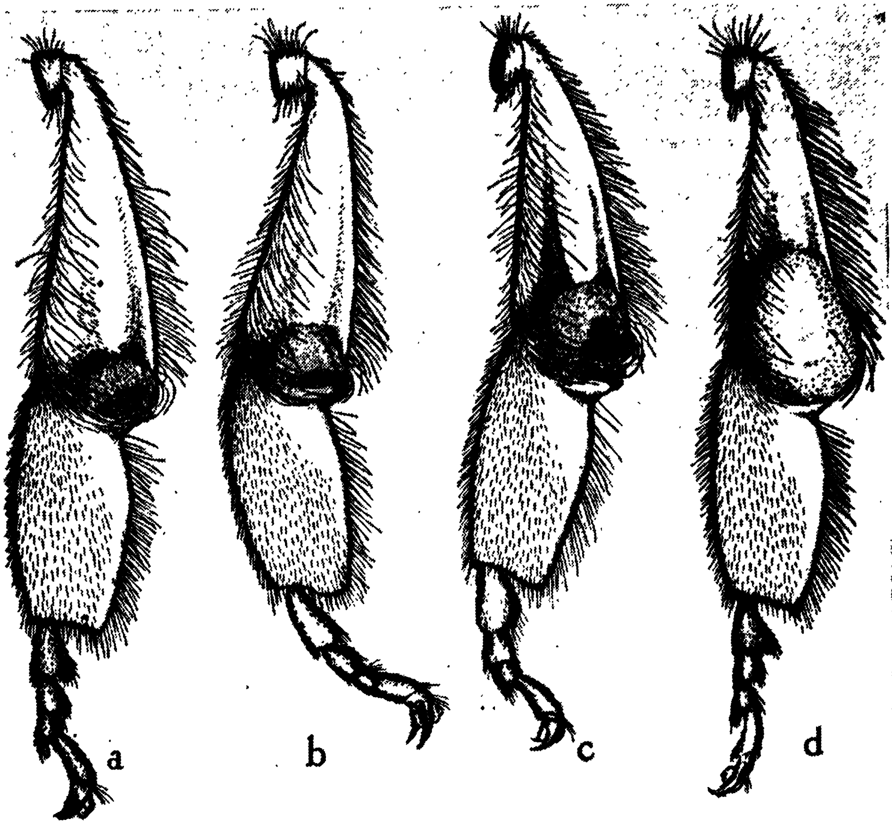



FIGURE 55. Outer surface of left hind legs of worker bees, showing the manner in which pollen enters the basket. a, Leg from a bee just beginning to collect. The planta (basitarsus) is extended, thus lowering the auricle, and the pollen mass lies at the entrance of the basket. b, A slightly later stage, showing the increase in pollen. The planta is flexed, raising the auricle. The hairs, extending outward and upward from the lateral edge of the auricle, press upon the lower and outer surfaces of the small pollen mass, retaining and guiding it upward into the basket. c,d, Slightly later stages in the successive processes by which additional pollen enters the basket. (*After Casteel*)

The second pair of legs collects free pollen from the thorax, more particularly from the ventral region, and receives the pollen collected by the first pair of legs. In taking pollen from the fore leg, the middle leg of the same side is extended forward and is either grasped by the flexed fore leg, or rubbed over it as the fore leg is bent downward and backward. Much sticky pollen is now assembled on the inner faces of the broad tarsal segments of the second pair of legs.

Pollen is transferred to the pollen baskets in at least two ways. A relatively small amount may reach the pollen baskets directly, as the middle legs sometimes are used to pat down the pollen accumulated there (Fig. 54, center). But by far the larger amount is first transferred onto the pollen combs on the inner surfaces of the hind legs. One of the middle legs and then the other alternately is grasped between the plantae of the

hind legs and then drawn forward and upward, thus combing the pollen from the middle legs. The pollen now held in the combs of the hind plantae* is next transferred to the pollen baskets on the outer surfaces of the hind tibiae.

With the two hind legs drawn up beneath the abdomen, the pollen combs of one leg are scraped by the pecten spines of the opposite one as the legs are moved up and down in a sort of pumping action (Fig. 54, right). Thus the pollen removed from one planta (basitarsus) is caught on the outside of the pecten comb of the opposite leg, the two combs scraping alternately. The planta is gently bent backward bringing its auricular surface into contact with the outer side of the pecten comb. By this action, the pollen mass is pushed along the slightly sloping lower end of the tibia, and thence out onto the surface of the pollen basket at its lower end (Fig. 55). Each new addition of pollen is pushed against the last and, simultaneously, the masses of pollen on both legs grow upward, a very small amount being added at each stroke.

Finally, each leg is loaded with a mass of pollen, held in place by the long recurved hairs of the elevated margins of the tibiae. If the loads are very large, these hairs are pushed outward and become partly embedded in the pollen, allowing the mass to project beyond the margins of the tibiae.

The bee accomplishes these brushing and combing actions so rapidly that the observer probably will fail to see some of the steps in the process without repeated observations (Fig. 56).

## STORAGE OF POLLEN

When the bee has fully loaded her baskets she hurries to the hive. Some walk leisurely over the combs, while others appear to be greatly agitated, performing the characteristic "dance" which announces to the other fielders the existence of a source of pollen. Many pollen-bearing bees eagerly solicit food from other workers or take it from the cells.

Presently the pollen bearer will be seen to put her head into cell after cell as if looking for a suitable place to leave her load. For no apparent reason a certain cell will be selected which often is situated in the area immediately surrounding the brood, above and to the sides. The bee grasps one edge of the cell with her fore legs and arches her abdomen so that its posterior end rests on the opposite side of the cell. The hind legs are thrust into the cell and hang freely within it. The middle leg of each side is raised and its planta (basitarsus) is brought into contact with the upper end of the tibia of the hind leg. The middle leg now is pushed between the pollen mass and the corbicular surface so that the mass is pried outward and downward and falls into the cell. The hind legs now execute cleansing movements to remove any remaining bits of pollen.

*"Planta" as here used is the *basitarsus* of Snodgrass (see Figs. 244 and 245 in Chapter XIX, "The Anatomy of the Honey Bee").

FIGURE 56. A worker bee in this characteristic manner collects pollen from the apple blossom. ("*Honey Bee*," *Encyclopædia Britannica Films Inc.*)

After ridding herself of the two pellets, the bee usually leaves the cell without paying further attention to its contents. Another worker, one of the so-called house bees, attends to the packing, breaking the lumps with her mandibles and tamping the material into the bottom of the cell. It seems practically certain that the chemical composition of the stored pollen, or "beebread," is changed somewhat by the action of liquids added during the process of collection and at the time of packing, or later.

### TIME FACTORS

Time records on bees gathering pollen from corn (*Zea mays*) were secured in 1920, and again in 1921 (see reference No. 51 in this chapter). Weather conditions in both years were favorable enough for the production of pollen by the plant and for field work on the part of the bees. In 1920, there was an abundance of bloom, whereas, in 1921, the main period of bloom had already passed.

Field trips by pollen bearers were found to be considerably shorter, as a rule, than those made by nectar carriers. Almost 40 per cent of the trips recorded for 1920 lasted from 6 to 10 minutes, and 97.5 per cent were completed in 30 minutes or less (Fig. 57, left). Only 20 per cent of the 1921 trips lasted from 6 to 10 minutes, yet 99 per cent were completed in 30 minutes or less. The most frequent time interval, however, was 15.5 minutes in 1921, as against 8.6 minutes in 1920.

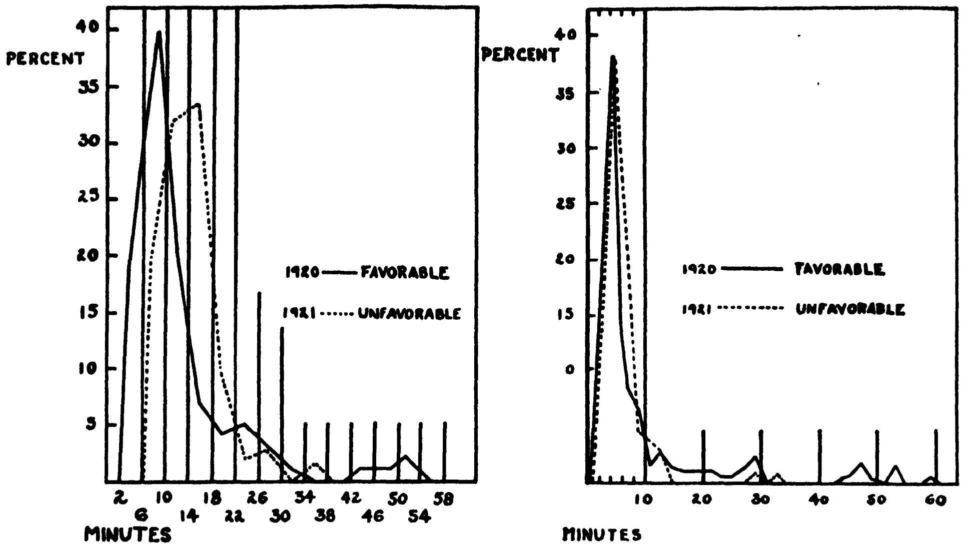



FIGURE 57. Frequency distribution of time records for pollen carriers when gathering from corn under *favorable* and *unfavorable* conditions. At left, field trips made by pollen carriers. At right, hive stays by pollen carriers. (*Graphs by O. W. Park*)

The time spent within the hive was very similar during the two seasons, the majority of hive stays lasting from 2 to 4 minutes (Fig. 57, right), with the most frequent interval being 3.4 minutes in 1920, and 3.7 minutes in 1921. The most frequent time for a round trip in 1920, was 12.6 minutes, but was 16.5 minutes in 1921. The two curves are much alike as to area and shape, but the one for 1921 (Fig. 57, left) stands about 4 minutes farther to the right, indicating in a general way that the bees consumed about 4 minutes more per trip than did those in 1920, when pollen was more plentiful.

The maximum number of trips in one day was 20 in 1920, and only 11 in 1921, while the averages were about 8 and 5, respectively. As a rule, corn pollen was not available in the afternoon, so these results represent only about half a day in actual working time.

## LABOR FACTORS

The weight of pollen loads carried by bees apparently differs according to the source,[54] ranging from 12 milligrams for elm and 14 for corn to 25 for apple and 29 for hard maple. The minimum flying weight of the bee was determined by three different methods,[55] all of which gave approximately 82 milligrams as the average for Italian bees. Thus the maximum load of pollen is about one-third of the weight of the bee.

[54]Park, Wallace (O.W.). 1922. Time and labor factors involved in gathering pollen and nectar. *Amer. Bee Jour.* **62**:254-255.
[55]Park, Wallace (O.W.). 1925. The minimum flying weight of the honeybee. *Iowa State Apiarist Rpt.* **1924**:83-90.

A pollen carrier making 8 trips—the forenoon average for 1920—and carrying 14 milligrams of corn pollen at each load would add about one four-thousandth of a pound to the food supplies of the colony; while one making 5 trips—the forenoon average for 1921—and carrying ordinary loads would bring in one six-thousandth of a pound in a half day of working time. On this basis it requires around 4 to 6 thousand pollen carriers to bring in a pound of pollen from corn during a forenoon in pleasant weather.

## Both Pollen and Nectar at One Trip

A question frequently asked is: Does a bee ever collect both pollen and nectar on one trip? The answer is: Yes, emphatically! Most plant species visited by honey bees produce pollen and nectar simultaneously. For those species that are dependent upon insects for pollination such a combination is essential for, in general, flowers not baited with nectar seldom have insect visitors. When visiting flowers in which both pollen and nectar are available, a goodly percentage of foragers take both.

Parker[56] gives a list of 31 Iowa plant species and data relative to the kind of load obtained by each of the bees observed at work on them. From corn and four species of roses, bees took pollen only, while from the remaining 26 species some took pollen only or nectar only, but many took both. The percentages of bees observed to gather both pollen and nectar varied all the way from a low of 2 for plum to a high of 95 for asparagus, while for Tartarian honeysuckle, strawberry, yellow sweet clover, alsike, and white clover the percentages ranged in the neighborhood of 40 to 50. Of the total of more than 13 thousand bees observed, 25 per cent were gathering pollen only, 58 per cent nectar only, while 17 per cent were collecting both on the same trip. Thus, while some bees go out strictly for pollen and others solely for nectar, a very considerable proportion of foragers gather more or less of both when available in the particular species of flower being visited.

## Activities of Propolis Workers

It has been known for a long time that bees collect a resinous substance, known as propolis, from the buds and the bark of trees and other plants. Although small amounts of this material may be gathered throughout the season, the bulk of it usually is brought into the hive during the latter part of summer after the main honeyflow and during the early fall. Bees can gather propolis only when the temperature is high enough to render it plastic. Some races and strains of bees use very little while certain others, notably the Caucasian race, use it extravagantly—much to the

[56]Parker, Ralph L. 1926. The collection and utilization of pollen by the honeybee. *Cornell Univ. Agr. Exp. Sta. Mem.* **98**.

disgust of the beekeeper because manipulation of the hive parts is greatly hindered.

Alfonsus[57] has described the method of gathering and certain conditions under which collection takes place. The bee alights close to a drop of resin appearing on the trunk or branch of a tree. With her mandibles she tears out a chunk of the gluey material which strings out but finally separates from the original drop. The thread of propolis then is removed from the mandibles with the middle legs and is deposited directly into the pollen baskets. This operation is repeated until a large drop of it adheres to each hind leg, shaped more or less like a pollen pellet.

When the propolis collector reaches the hive, other workers remove the sticky mass from her legs. It seems to be hard work, for these bees take a firm hold on the supporting surface while they bury their mandibles in the propolis. They pull so vigorously that the collector often is unable to hold her position. Frequently the collectors are freed of their loads in a similar manner at the hive entrance. During the removal process little pieces, or entire loads, sometimes are dropped accidentally and stick to various parts of the hive. Astor[58] noticed that propolis-laden bees in passing through the hive walk with their hind legs close together in such a way as to take the least possible space. He concluded that they took this precaution in order that they might not soil their companions by touching them with the sticky loads.

Little appears to be known concerning the manipulation of propolis by worker bees, but it is probable that a proportion of beeswax is added thereto, possibly to make it less sticky or more workable at certain temperatures. The hive bees carry the propolis with their mandibles to the place where it is to be applied. Cracks and crevices through which bees cannot pass are chinked up. It also may be used to smooth over the interior of the hive, to cover unwanted objects too large to remove, to varnish the interior of brood cells prior to each occupancy, and to strengthen comb attachments. Caucasian bees are inclined to reduce the entrance, utilizing large amounts of propolis for this purpose.

Philipp (see reference No. 21 in this chapter) and other European apiculturists consider that there are two kinds of propolis: One being the resinous material gathered from plants, principally trees; the other being produced within the body of the bee—probably in the honey sack—as the result of consumption of pollen. According to Philipp, the propolis gathered from trees and other plants serves largely for closing holes in the hive, and is of a different color which does not darken with age. It can be gathered only at moderate temperatures while the substance, which he calls *balm,* is always produced whenever bees eat pollen.

In the process of digestion, Philipp assumes that the indigestible gum of the pollen shells becomes free and, after being pressed across the hairs

[57]Alfonsus, E. C. 1933. Some sources of propolis. *Gleanings in Bee Culture* **61**:92-93.
[58]Astor, Alex. 1899. Notes d'un observateur. *Revue Internat. d'Apicult.* **21**:252-257.

on the lips of the "stomach mouth" (proventriculus), it comes into the oesophagus and is regurgitated. He states that balm is perfectly transparent, of a golden-greenish color, and is easily distinguished from propolis gathered from plants. Under the microscope, balm invariably shows pollen shells and little hairs which never are to be found in propolis obtained outside the hive. He considers that the greater part of all propolis in the hive is this by-product of the digestion of pollen.

Betts[59] raises objection to Philipp's hypothesis concerning the regurgitation of this balm, stating that the bee does not possess the muscles necessary for such a process. It is evident that much still remains to be learned concerning propolis.

The most important part of Philipp's contribution perhaps is the discovery that every newly built cell is coated with this balm before eggs are laid in it, and, following its use as a brood cell, its inner surfaces are revarnished before the queen will again lay in it. He states that it contributes to the stiffness and solidity of the combs, and that also the interior hive surfaces, including exposed portions of nails and wires, are coated with it. This balm, he believes, probably serves an important purpose in the disinfection of all surfaces within the hive, especially the interior of cells. With age, the balm grows darker, and Philipp suggests that this may be the reason brood combs are so black when old.

## How Bees Make Honey

Let us first consider the question: Why do bees make honey? Yes, you have it! Honey, including nectar, the raw material from which it is made, is the sole essential food of adult honey bees. The very existence of every colony hinges upon whether it is able to manufacture and store a sufficient quantity of honey during the honeyflow to tide it over periods of adversity, such as dearths in summer and cold in winter. There must be ample stores of honey within easy reach of the winter cluster, for then honey serves not only as nourishment for the body but also as the source of heat to keep the cluster warm. We must not lose sight of the fact that, unlike other insects, the honey bee is unable to hibernate.

Thus we see that honey bees are compelled to make honey if they are to survive. So Nature has provided these "creatures of instinct" with an irresistible impulse to gather nectar and lay up stores of honey *without limit* as long as nectar or other sweet liquid is available. In this respect they possess no terminal facilities—no power to reduce or stop either the hoarding instinct or the activities that result therefrom, no matter how much honey may be on hand already. And that is what makes it possible for man to appropriate for his own use a portion of the hard-earned store of sweets, each pound of which represents the life blood of several hundred

---

[59]Betts, Annie D. 1926. (Editor's note.) *Bee World* 7:165.

FIGURE 58. Rock painting representing a gatherer of wild honey, from the New Stone Age period, discovered at the Cuevas de la Araña (Spider Cave) near Bicorp in Valencia, Spain. Actual size. (*From H. Obermaier's "Fossil Man in Spain"*)

workers. It has been aptly stated that bees are man's best little friends. Throughout untold generations (Fig. 58) they have unwittingly supplied him with food, drink, light, and medicine.

It has been said that the history of honey is the history of mankind. Evidence that honey was prized highly by cave dwellers of the New Stone Age came to light in 1919, when a prehistoric rock painting was discovered at Cuevas de la Araña (Spider Cave) in Valencia, Spain.[60] The figure shown scaling the face of the cliff, by means of long ropes presumed to be woven of sedge grass, has reached a hole in the cliff apparently occupied by bees. With her right hand she is taking honeycomb out of the hole while in her left is a basket in which to carry it home. A number of crude figures doubtless intended to represent "angry" bees are flying around the gatherer of wild honey.

---

[60]Obermaier, Hugo. 1924. *Fossil Man in Spain*. pp. 250-251. New Haven. Yale Univ. Press.

The most ancient writings of historic times show that bees were cultured and that honey was used extensively. It was an important commodity and was used as a medium of exchange in place of money. Taxes, rentals, and tributes often were levied in terms of honey or beeswax or both. Honey was the exclusive sweetening agent in those days and remained the universal sweet of the ages almost to times within the memory of persons still living.

### The Beehive a Factory

The beehive is a factory—its chief products beeswax and honey. But, strange as it may seem, there is a by-product of far greater value to man than the combined output of the two chief products. That by-product is the service of pollination performed unwittingly by the field hands while harvesting the raw materials without which the factory cannot operate.

Numerous comparisons can be made between the beehive and factories in general. Indeed one need but mention such terms as organization, management, labor, wages, ownership, dividends, raw materials, processing, packaging, products, and output, to set going in our minds a flood of comparisons.

But the beehive is far more than a factory. In certain respects, it is much like the first factories that came into existence, where the home served as working quarters and all work, even to the bringing in of raw materials and the making of furnishings and equipment, was performed by the members of the one household. Like the earliest factories, all products made in the beehive are solely for communal use. Honey that finds its way into human trade channels does so by virtue of man's prerogative to take advantage of the honey bee's trait of storing an abundance of this product against its own possible future needs.

Let us first touch briefly upon some elements of dissimilarity. Who ever heard of any other factory with no discernible superintendent, foreman, or manager? Who ever heard of jobs being assigned on the basis of the age of the laborer? Who ever heard of workers without complaint giving a lifetime of toil with no expectation of wages other than bare subsistence? And who ever heard of any other factory in which communism is carried to its ultimate logical conclusion, where each individual exists for the whole but the whole exists for no individual? Here the individual is born to serve and, upon ceasing to do so, forfeits the right to live. Obviously the problem of labor strikes never arises in this factory.

Formerly, the queen was believed to be the ruler, but we now know her to be the veriest slave—an automaton—in short, an egg-laying machine. And although no superintendent has been found, it has been recognized for centuries that various jobs within the factory and in the field are in some way apportioned among the laborers. Evidence now indicates age as the primary basis for job assignment, but a shortage of hands for one operation may be filled by a surplus from others.

## Raw Materials

Our honey factory, like other factories, requires various raw materials. The principal ones are nectar, pollen, water, and propolis. Only the first named enters directly into the manufacture of honey, whereas the other three are necessary to the maintenance and welfare of the establishment and its workers. Pollen is an essential ingredient of larval food, as also are nectar (or honey) and water. Water is needed principally by nurse bees for the elaboration of larval food. Propolis is used for closing undesirable openings in the hive and for varnishing its interior.

Nectar is a sweet liquid secreted by plant nectaries usually located within the flowers, but in some species they are situated elsewhere. Nectar is the reward offered to bees and other insects in return for their indispensable services in cross-pollination. It is composed almost entirely of sugar and water, but the proportion of these ingredients varies widely. In Iowa, the sugar content of nectar usually lies between 20 and 60 per cent, with a fairly common average of 40 per cent. Honey, too, is composed largely of sugar and water but in the fairly constant proportion of 80 per cent sugar and 20 per cent water. The sugar in nectar, however, is

FIGURE 59. A worker bee sipping nectar from an apple blossom. Note that the pollen present in the basket on the hind leg clearly demonstrates that bees often collect both pollen and nectar at one trip. ("*Honey Bee,*" *Encyclopædia Britannica Films Inc.*)

mostly sucrose (cane sugar) while that in honey is made up of nearly equal parts of two simple sugars, dextrose and levulose (see Chapter XV, entitled "Honey"). Thus it will be observed that nectar becomes honey only after it has been gathered, processed, and stored in the comb by the bees.

### Behavior in Collecting Nectar

Sight and smell enable bees to locate sources of pollen and nectar. Technique employed in visiting flowers depends upon whether the forager seeks pollen only, nectar only, or both of them, and differs also with the type and size of flower. A fielder collecting nectar only, when in flight, carries her hind legs well apart, hanging at ease beside the abdomen. If the size of the flower permits, as in the apple blossom, the bee alights within the flower (Fig. 59). But if small, as in hard maple or sweet clover, she alights upon any convenient part of the plant that will support her weight. Upon alighting, the proboscis is brought forward from its inactive position beneath the "chin" and is inserted into that part of the flower where nectar accumulates. Typically this is at the bottom of the corolla, as in the florets of clover.

In visiting flowers such as red clover, with deep corollas too narrow for the bee to enter, the forager often can reach but little, if any, of the nectar that may be available, but in the case of small or open flowers she is able to get all available nectar without difficulty. For information relative to the manner in which liquids are taken up through the proboscis, the reader is referred to Chapter XIX, "The Anatomy of the Honey Bee."

Observations on field bees at work suggest that a bee cannot tell whether there is nectar in a given blossom without inserting her proboscis. By this means, however, she very quickly determines its presence or absence. When nectar is found, she remains to suck until all nectar within reach of her proboscis has been taken up. In case none is found, the proboscis is withdrawn immediately and she passes on to another flower or floret without delay, unless she lingers to gather pollen, or perhaps to brush from her hairy body and pack securely in her pollen baskets such grains of pollen as may have been acquired during her search for nectar.

When working on white clover (*Trifolium repens*), for instance, the forager tests out a head by thrusting her proboscis successively into several corollas. If she gets nothing from these, she flies to another near-by head, but, if she finds an abundance of nectar, she will continue to reach into one corolla after another until a goodly number of the florets of proper age for nectar secretion have been tried out. As a rule the search is not so systematic but that numerous florets are passed over without investigation. The experienced observer understands that when bees flit lightly from flower to flower, pausing only momentarily to insert and withdraw the proboscis, they are obtaining little or no nectar; but when they sit and

suck for an appreciable time from a majority of the flowers, they are harvesting an abundance of nectar.

While it seems certain that a bee is unable to distinguish which of two similar flowers contains no nectar, she apparently can detect, probably through the sense of smell, such flowers as have been visited recently, for upon alighting upon such a flower the forager commonly takes wing without bothering to insert her proboscis. After a time the odor, doubtless, disappears so that a later visitor, finding no deterrent odor to warn of a recent predecessor, will proceed to explore the flower with her proboscis.

### Number of Visits to Get a Load

Most nectariferous plants secrete nectar only in minute quantities so that rarely, if ever, is it possible for a forager to fill her honey sack with a single deep draft from one blossom. One might expect, however, that a bee visiting the blossoms of tulip poplar (*Liriodendron tulipifera*), in which nectar sometimes may be found in exceptional quantities, should occasionally get a load from a single flower. But with most plants a forager must visit many blossoms to secure even a moderate load. According to Dr. Miller,[61] Rauschenfels, an Italian authority on bees, held that on one trip a bee visits from 50 to 1000 blossoms. On one occasion he followed a forager while she visited 640 flowers before losing sight of her, but unfortunately the plant species involved is not reported. Owing to the difficulty of following a bee throughout the entire course of a trip, exact data are lacking, but calculations based upon incomplete data suggest that several hundred visits may be necessary to obtain a load of nectar from small flowers such as those of sweet clover (*Melilotus*). And any species from which a load may be gathered in less than 100 visits should be a highly desirable honey plant; from it large loads could be secured in a relatively short time, thus permitting numerous trips per day for each fielder. Other things being equal, size of nectar load depends upon the abundance or scarcity of nectar, so the size of loads brought into the hive is a fair index to the intensity of the honeyflow.

### Behavior of Incoming Nectar Gatherer

The loaded fielder hustles through the entrance and into the hive with the air of one bent upon important business. Once she has reached a place among fellow workers on the comb, her conduct depends largely upon conditions she has just encountered in the field. If the source from which her load was obtained is well known to the other fielders, she walks about until she meets a house bee to which she gives part of her load. Occasionally she gives her entire load to a single house bee, but more often she distributes it among three or more. The reason for this is not clear unless it may be that their honey sacks are partly full.

---

[61]Miller, C. C. 1902. Stray straws. *Gleanings in Bee Culture* 30:136.

*The Dance*

If the nectar source is bountiful, the loaded nectar gatherer usually performs the peculiar dance already referred to as a means of communication. During this performance, the loaded nectar carrier shakes her abdomen vigorously from side to side, all the while running in arcs of circles, turning first to one side and then to the other. Usually she is followed by four or five other bees and while she continues her dance, every now and then, one of the interested followers may be seen to leave for the field until, by the time the dancer is ready to depart, a dozen or more may have left to search out the source of the rich find already discovered by the dancer. Some leave immediately upon coming in contact with the dancer, but others appear to find it necessary to prepare for the trip by securing a little food from other bees, or from a cell. As a rule each new recruit leaves for the field in less than 2 minutes after her first contact with the dancing fielder.

It is to be noted especially that most of the recruits leave the hive *before* the dancer does. They *do not follow* the latter to the source of supply as has been assumed generally. Each must seek out for herself the new source of supply, using whatever information the dancing nectar carrier may have been able to convey to her (see "Communication Among Bees" in this chapter). Lineburg[62] has suggested that the searcher possibly may be guided to a greater or lesser extent by a trail of odor given off from the body of the returning fielder on her way to the hive.

Returning foragers, as already stated, perform the recruiting dance only so long as a bountiful source of supply is available. Thus, no more workers than may be profitably employed at a given source are induced to go in search of it.

This doubtless accounts for the commonly observed fact that only in exceptional instances is there any perceptible competition among foragers over any particular flower, or group of flowers. It is a fact worthy of notice that, even when blossoms are hard to find, bees are scarcely more numerous on those in or near the apiary than on those at a considerable distance. While the number of bees per unit of forage area of a given plant species normally is somewhat greater within a radius of, let us say, a quarter mile from the apiary than at a distance of a mile and a quarter, the rate at which the bee population decreases as the distance from the apiary increases is considerably less than is generally supposed.

*Transfer of Load to House Bee*

But now to return to the dancing forager. At irregular intervals she pauses long enough to pass out a taste of her booty to one or another of the near-by workers. But soon she meets a house bee to which she gives

[62]Lineburg, Bruce. 1924. Communication by scent in the honeybee—a theory. *Amer. Naturalist* 58:530-537.

a considerable portion of her load. As they approach each other, the field bee opens her mandibles wide apart and forces a drop of nectar out over the upper surface of the proximal portion of her proboscis, the distal portion being folded back under the "chin." Assuming that the house bee approached is not already loaded to capacity, she stretches out her proboscis to full length and sips the proffered nectar from between the mandibles of the fielder (Fig. 60, *A*). While the nectar is being transferred in this manner, the antennae of both bees are in continual motion, and those of one bee are constantly striking those of the other. At the same time, the house bee may be seen to stroke the "cheeks" of the field bee with her fore feet as if eagerly coaxing for more.

*Departure of Field Bee*

Upon disposing of her load, a nectar gatherer sometimes leaves for the field immediately, but usually she pauses long enough to secure a small amount of food. In any case her departure is immediately preceded by certain characteristic maneuvers which remind one of the last-minute preparations of a woman "prettying" herself before going out on the street. She first gives her proboscis a swipe between her fore feet, then rubs her eyes, and often cleans her antennae. Then, with a quick look around, she takes her bearings and forthwith starts for the field with an air of urgency and decision. Once aware of the significance of these preliminary maneuvers, one need never doubt the intention of a forager that so behaves. The entire process of disposing of her load often is accomplished in less time than it takes to describe it.

## Storing and Ripening

In the manufacture of honey from nectar, two distinct processes are involved: One brings about a chemical change in the sugar which makes it more easily digested, and the other results in a physical change whereby surplus water is eliminated. The sugar in nectar is largely cane sugar but as soon as it is taken into the honey sack of the field bee there begins a process, known as inversion, which rapidly changes most of the cane sugar into two simple sugars, dextrose and levulose.

There are at least two distinct phases of the water-elimination process. If we follow one of the house bees after she has received a load of fresh nectar, we will find upon close observation that she manipulates this nectar with her mouthparts[63,64,65,66] in such a manner as to expose it in a thin film to the warm dry air of the hive. This results in the rapid evaporation of a considerable part of the excess water. After manipulating this drop for from 10 to 20 minutes, she deposits it in a waxen package,

[63] Gallup, Elisha. 1868. Evaporating nectar. *Amer. Bee Jour.* 3:172. [Dr. Gallup of Osage, Iowa, appears to have been the first to call attention to this behavior.]

[64] Doolittle, G. M. 1876. Various matters. *Gleanings in Bee Culture* 4:74-76.

[65] Miller, Arthur C. 1904. A mysterious act. *Amer. Beekeeper* 14:7-8.

[66] Park, Wallace (O.W.). 1925. The storing and ripening of honey by honeybees. *Jour. Econ. Ent.* 18:405-410.

which we know as a cell in the honeycomb, where further evaporation continues, until by the end of about 3 days such nectar reaches a sugar concentration of about 80 per cent. At this stage, the bees apparently recognize it as fully ripened honey and seal the tiny hexagonal packages with caps which they construct of beeswax.

### *Role of the House Bee*

When the house bee has received her portion of the field bee's load, she meanders about the hive in search of a place where she will not be crowded. Here she usually takes up the characteristic position shown at *B* in Figure 60, having the long axis of her body in a perpendicular position with head uppermost. She at once begins to go through a series of operations which are illustrated diagrammatically at right in Figure 60.

Starting with the mouthparts at rest, as shown in the first diagram, the mandibles are opened wide and the whole proboscis is moved somewhat forward and downward. At the same time the distal portion of the proboscis is swung outward a little and a small droplet of nectar appears in the preoral cavity, as shown in the second diagram. The whole proboscis is then raised and retracted almost to the position of rest, but is depressed again, and is again raised as before, and so on. With each succeeding depression, the distal portion of the proboscis swings outward a little farther than before, but it makes only the beginning of a return to its position of rest.

Accompanying the second depression of the proboscis an increased amount of nectar appears in the preoral cavity, some of which begins to flow out over the upper surface of the proboscis. As the proboscis is raised and retracted the second time, the beginning of a drop of nectar usually may be seen in the angle formed by its two major portions, as shown in the third diagram. This droplet increases in size each time the proboscis is alternately depressed and raised until a maximum droplet is produced, as illustrated in the fifth diagram. The bee then draws the entire drop inside her body.* As the nectar begins to be drawn in, the drop assumes a concave surface at its lower end, as shown at *a* in the sixth diagram. The distal portion of the proboscis is extended as at *b* until the drop has disappeared, when it is again folded back to the position of rest indicated at *c*.

A house bee commonly spends from 5 to 10 seconds in carrying out the series of activities illustrated at right in Figure 60. This procedure is repeated with only brief pauses for about 20 minutes, although both of these intervals are subject to considerable variation. Upon the comple-

---

*A somewhat similar activity on the part of certain species of solitary bees of the genus *Halictus* has been reported by Tarlton Rayment (The wild bees of Australia. *Australasian Beekeeper* 33:94-97. 1931). Although the procedure of these Halictines differs considerably from that of the honey bee, there can be no doubt that its purpose is the same. An interesting sketch illustrating this behavior accompanies the article. At the time his article was written, Rayment was unaware that the behavior in question had been reported for any other species.

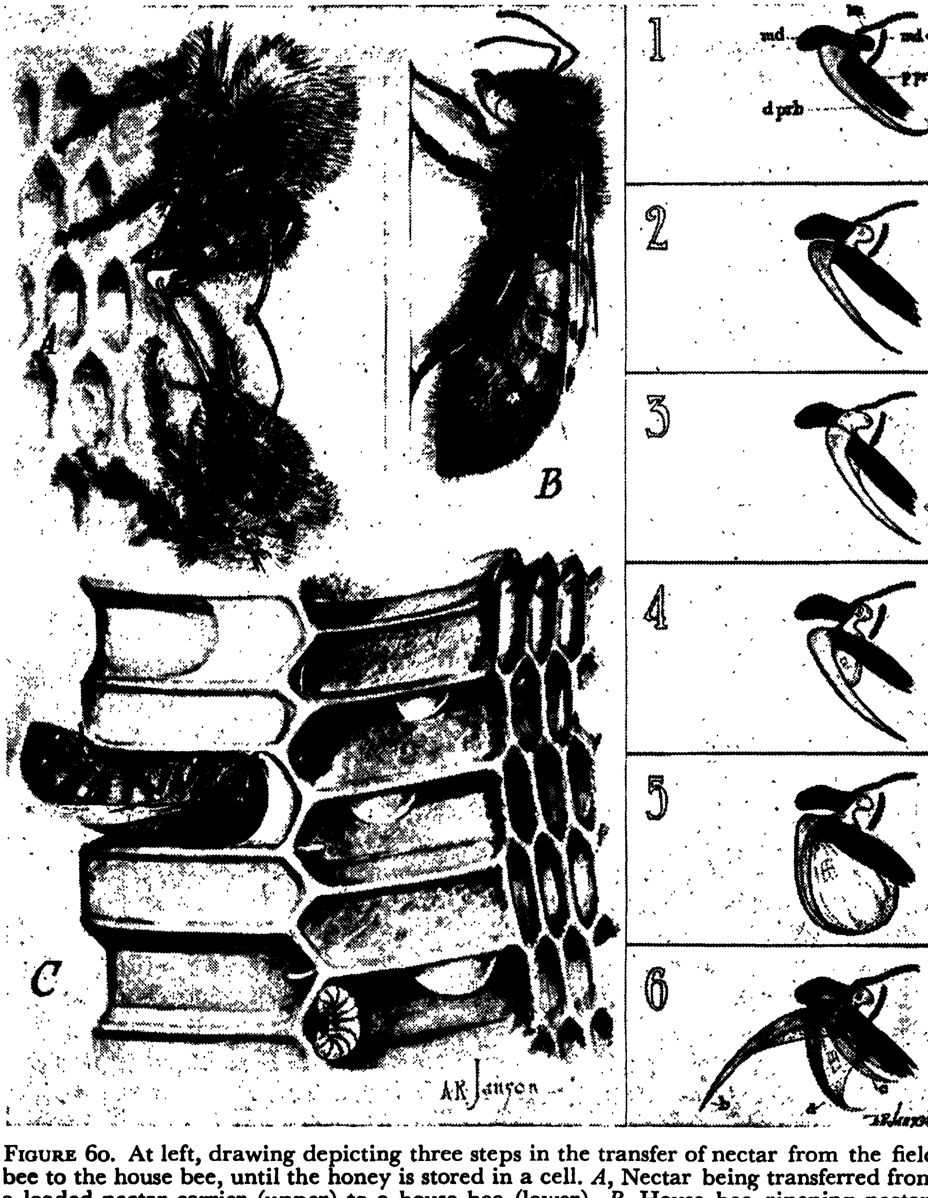



FIGURE 60. At left, drawing depicting three steps in the transfer of nectar from the field bee to the house bee, until the honey is stored in a cell. *A*, Nectar being transferred from a loaded nectar carrier (upper) to a house bee (lower). *B*, House bee ripening nectar. *C*, House bee depositing nectar or unripe honey. At right, diagrammatic sketches of the mouthparts of a bee engaged in transforming nectar into honey. See text for description of process. (*Drawn by A. R. Janson, under the direction of O. W. Park*)

tion of this part of the ripening process, the bee searches out a cell in which to deposit the drop she has been concentrating. Into this cell she crawls, ventral side uppermost, as shown in Figure 60, *C*. This position is characteristic of a bee depositing unripe honey. If the cell is empty, she

enters until her mandibles touch the upper rear angle of the cell. The honey is forced out over the dorsal surface of the folded proboscis, between the mandibles, which are held well apart. Then, using the mouthparts as a brush, and turning her head from side to side, she "paints" the unripe honey across the upper wall of the cell so that it runs down and occupies the rear portion of the cell. But if the cell already contains honey, she dips her mandibles into it and adds her drop directly without the "painting" process. Previous observations only partially covered this important activity of the house bee. Thus, the earlier observations of Gallup, Doolittle, Arthur C. Miller (see references Nos. 63, 64, and 65), and others were verified and extended.

When nectar is coming in rapidly, and particularly if it is very thin, the house bees do not always stop to put it through the ripening process, but deposit it almost at once. Instead of depositing the entire load in a single cell, the house bee often distributes it by attaching a small drop to the roof of each of several cells as shown in three cells in Figure 60, *C*. The hanging drop exposes a maximum surface for evaporation.

Sometimes droplets thus "hung up to dry" may be seen in super combs, but usually they are to be found in greater abundance in cells within the brood nest, where the air is especially warm and doubtless dry. And they are fully as apt to be found in cells that contain eggs or young larvae (Fig. 60, *C*) as in empty ones. Later these droplets are collected and it is assumed that they are then put through the process of ripening by manipulation. Whether the nectar, or perhaps it should be called unripe honey, ordinarily is put through this phase of the ripening process repeatedly before it becomes fully ripened is a moot question, but it seems probable that some of it may be worked over several times.

The procedure described above results in the rapid evaporation of water from the freshly gathered nectar and, therefore, corresponds to the "boiling-down" process so well known in connection with the manufacture of sirup and sugar from the sweet sap of the sugar maple. The other important phase of the honey-ripening process, the inversion of sugar, may be expedited by this process also. Although it was found that the inversion process begins while the nectar is being gathered and carried to the hive, it is just possible that more invertase may be added by the house bee while thus manipulating the nectar prior to depositing it in the comb.

Since the change from nectar to honey takes place gradually over a period of many hours, the question arises as to just when nectar ceases to be nectar and becomes honey. Apparently an intermediate stage exists for which there is no specific name. Beekeepers often use such terms as *new, green,* or *unripe* to describe honey which is not ripe. For the sake of clarity it is suggested, therefore, that the term *nectar* be restricted to the sugary liquid secreted by nectaries up to the time this product is deposited in the comb, after which it may be referred to as *unripe* honey until its concentration approximates that of ripe honey.

Studies[67] reported, in 1933, show that nectar containing 45 per cent sugar when brought into the hive was found to contain approximately 60 per cent sugar when first deposited in the comb as unripe honey. Since in no case did it remain in the comb to exceed 30 minutes, direct evaporation after deposition in the cells would be wholly inadequate to account for any considerable part of the observed increase. It is believed, therefore, that this 15 per cent advance in concentration is attributable to the activities of house bees in manipulating the nectar by means of their mouthparts prior to depositing it in the comb.

*Evaporation from Open Cells*

Experiments to determine the rate of increase in concentration of nectar and of sugar solutions placed within the hive but screened from the bees were reported by the author, [68, 69] in 1927 and 1928, respectively. Using nectars and sugar solutions of various initial concentrations, it was shown that the rate of advance in concentration was about twice as great in cells filled only one-fourth full as in those filled three-fourths full (Figs. 61 and 62). When circumstances permit, bees make excellent use of this fact by spreading out the newly deposited unripe honey, placing only a small amount in each cell, later to be gathered up and stored compactly before being sealed.

From cells filled one-fourth full, evaporation takes place at a rate sufficient to advance a sugar solution to the concentration of ripe honey within 3 days if the initial concentration is not less than 20 per cent, and within 2 days if the initial concentration is not less than 30 per cent. In cells filled three-fourths full, the 60 per cent solution reached the concentration of ripe honey after 2¾ days, the 40 per cent solution after 3¼ days, while the 30 and 20 per cent solutions required 4½ and 5 days, respectively.

In 1933, data were presented on the rate of evaporation of water from unripe honey newly deposited in the comb (see reference No. 67). The general plan of this study was to determine (1) the sugar concentration of the nectar when carried into the hive, (2) the concentration of the unripe honey when first deposited in the cells, and (3) the concentration daily thereafter until the concentration of ripe honey should be attained.

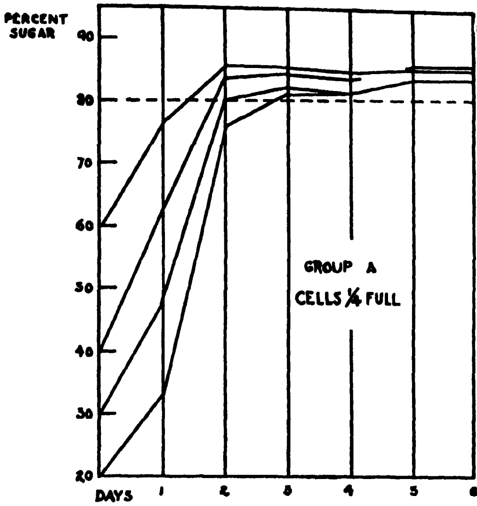
Loaded honey sacks of nectar carriers caught as they entered the hive provided the samples required for determining the sugar concentration of incoming nectar. Combs containing newly deposited unripe honey *only* were obtained by supplying a colony on three successive afternoons with empty combs which had been previously washed and dried. To preclude

---

[67] Park, O. W. 1933. Studies on the rate at which honeybees ripen honey. *Jour. Econ. Ent.* **26**:188-193.

[68] Park, O. W. 1927. Studies on the evaporation of nectar. *Jour. Econ. Ent.* **20**:510-516.

[69] Park, O. W. 1928. Further studies on the evaporation of nectar. *Jour. Econ. Ent.* **21**:882-887.



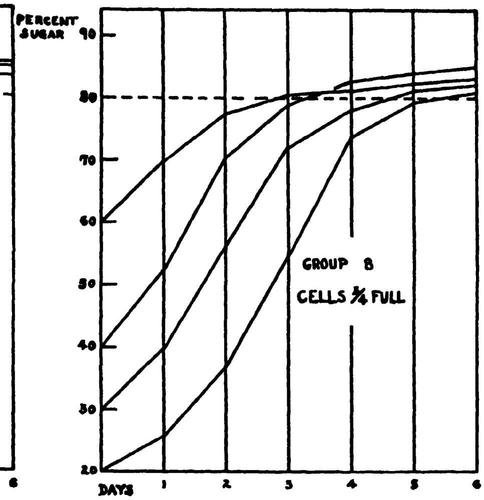
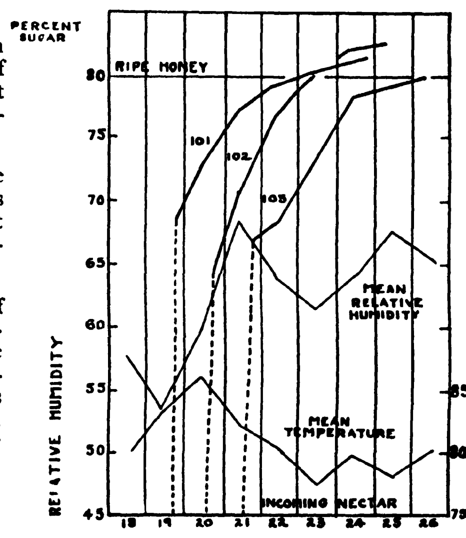




FIGURE 61. (At top left) Rate of increase in concentration of sugar solutions in cells of honeycomb placed within the hive but screened from the bees. Cells filled one-fourth full. (*Graph by the author*)

FIGURE 62. (At top right) Rate of increase in concentration of sugar solutions in cells of honeycomb placed within the hive but screened from the bees. Cells filled three-fourths full. (*Graph by the author*)

FIGURE 63. (At right) Rate of increase of sugar concentration during the honey-making process. The dotted lines show the increase in concentration during the afternoon the nectar was gathered. During this period the house bees hastened evaporation by manipulating the nectar with their mouthparts. Daily mean temperature and relative humidity for the period are shown. (*Graph by the author*)




the possibility of anything but unripe honey being stored in the comb, a strong colony was removed from its stand and replaced by a carefully prepared small one, composed almost entirely of bees too young to work in the field. The combs were designated by the numbers 101, 102, and 103, in the order in which they were used.

By comparing the concentration of the newly deposited honey with that of incoming nectar, a measure was obtained of the increase in concentration which is attributable to the activities of house bees in manipulating the nectar with their mouthparts, prior to depositing it in the combs. These comparisons are tabulated on the following page.

Increase in Concentration of Nectar Before Being Deposited

| Hour | Mean time in comb | Incoming nectar | Unripe honey soon after deposited | Increase |
|---|---|---|---|---|
| 1 p.m. | 30 min. | 35.5% | 55.8% | 20.3% |
| 2 p.m. | 15 min. | 49.8% | 57.2% | 7.4% |
| 3 p.m. | 15 min. | 42.8% | 61.0% | 18.2% |
| 4 p.m. | 30 min. | 53.4% | 61.4% | 8.0% |
| Average | | 45.1% | 58.8% | 13.5% |

Although too great reliance should not be placed upon the accuracy of individual values tabulated above, the averages should be fairly dependable and sufficiently representative to give a general idea of the effectiveness of this particular activity of house bees in bringing about rapid evaporation of moisture from the nectar. The mean concentration of incoming nectar recorded on this occasion is normal and typical for Iowa conditions. It appears probable, therefore, that the mean increase of nearly 15 per cent may be fairly typical for Iowa honeyflow conditions.

The concentration of incoming nectar, as determined throughout the afternoons of July 19, 20, and 21 is tabulated below:

Concentration of Incoming Nectar

| Hour | July 19 | July 20 | July 21 |
|---|---|---|---|
| 1 p.m. | 35.5% | 45.2% | 36.6% |
| 2 p.m. | 49.8% | 44.6% | 43.4% |
| 3 p.m. | 42.8% | 47.9% | 46.4% |
| 4 p.m. | 53.4% | 45.8% | |
| 5 p.m. | | | 52.6% |
| Average | 45.4% | 45.9% | 44.5% |

Since the averages for all 3 afternoons are almost identical, it may be considered that the honey stored was produced from nectar containing 45 per cent sugar on the average.

At the close of the storage period, after all the bees had been brushed off, combs 102 and 103 were placed in individual screen cages which then were inserted between combs of ripening honey in the second story of a populous colony. Comb 101 was treated in a similar manner except that the bees were allowed free access to it throughout the first night, the comb being caged early the following morning.

*Rate of Ripening*

Data on the rate of evaporation of water from open cells of unripe honey were obtained as follows: The sugar concentration for each comb was determined at the close of the afternoon on which the unripe honey was stored. Its concentration was determined again the following morning and at 24-hour intervals thereafter until the honey attained or surpassed the concentration of 80 per cent, which was taken as the standard for ripe honey.

Figure 63 is a graphic representation of the rate of increase in sugar concentration during the honey-ripening process. Increases which occurred during the afternoon storage period are shown for each comb by the dashed portion of the curve. The unexpectedly small advance in concentration shown for comb 103 during the first 24 hours after being stored may be attributed, at least in part, to a decided increase in humidity accompanied by a decrease in temperature, as may be noted from the accompanying graphs. The unripe honey left in the hive but screened from the bees advanced to approximately the concentration of ripe honey within about 3 days. The reduction in water content was due solely to evaporation from the cells. There are reasons to believe that when bees have free access to combs, as they do normally, they further hasten the evaporation by taking the unripe honey out of the cells and reworking it with their mouthparts as described heretofore.

Observations show that when adequate comb space is available, few cells are more than half filled with unripe honey at the close of a day of heavy flow, and many contain less. If such combs are shaken, unripe honey flies out freely. Examination first thing the next morning reveals important changes. The widely scattered cells that contained small amounts the preceding evening now are empty, while comb areas that were not quite full are now completely filled and cells in adjacent areas are fuller than they were. Scarcely a drop can be shaken from any comb. *Surely no one can doubt the wisdom of providing an abundance of comb space to facilitate the ripening process. It is an important consideration in the maintenance of colony morale.* While adequate comb space for evaporation may be provided readily enough in extracted honey production, its provision in comb honey production is a real problem because drawn combs cannot be used and also because crowded conditions usually are considered essential. This is one of the reasons why colony morale is so difficult to maintain under conditions of comb honey production.

## Excretion Theory

For centuries the idea that honey bees eliminate from nectar a considerable part of its surplus water, by means of some physiological process while in the honey sack, has been so widely held that a brief discussion of it, in the light of results of investigations by the author,[70, 71, 72, 73] seems to be in order.

The so-called excretion theory was based upon two observed and well-substantiated facts: That bees carrying thin sirup or nectar often expel

[70]Park, O. W. 1924. The storing and ripening of honey. *Amer. Bee Jour.* **64**:330-332.

[71]Park, O. W. 1927. How bees concentrate nectar. *Iowa State Hort. Soc. Rpt.* **61**:297-303. Also: 1927. *Iowa State Apiarist Rpt.* **1926**:62-67.

[72]Park, O. W. 1928. How bees remove water from nectar. *Iowa State Hort. Soc. Rpt.* **62**:379-383. Also: 1928. *Iowa State Apiarist Rpt.* **1927**:83-87.

[73]Park, O. W. 1932. Studies on the changes in nectar concentration produced by the honeybee, *Apis mellifera*. Pt. I. Changes which occur between the flower and the hive. *Iowa Agr. Exp. Sta. Res. Bull.* **151**.

droplets of clear liquid while in flight; and that honey newly deposited in the cells is more concentrated than the nectar from which it was produced. Bazin,[74] whose book is an adaptation from Reaumur's *Memoires,*[75] states that nectar "does not issue from the bee's body such as it entered; but it is digested and concocted there (and this likewise is the opinion of Swammerdam); which is the reason of its being thicker when it issues from the bee, than when she took it in."

Babaz,[76] whose book was published in 1868, is cited by Dadant[77] as the originator of the idea that bees rid nectar of a part of its surplus water by evacuating it during flight. In 1886, Planta[78] found by chemical analysis that unripe honey freshly disgorged by the bees, when it is delivered into a cell, is already concentrated to a considerable extent, but he offered no suggestion as to the means whereby this might be accomplished. Dzierzon, as quoted by Greiner,[79] stated, "It seems we can reasonably suppose that the honey stomach of the bee is like a filter, allowing the water to pass through its walls." Hasty[80] asserted, "Through a wide extent of very thin membrane, *made-a-purpose,* the water of the blood and the water of the nectar equalize rapidly."

Foremost exponent of the excretion theory was Brunnich,[81, 82, 83, 84] of Switzerland, who, after making certain anatomical studies and some experiments, stated that much of the excess water of nectar passes through the wall of the honey sack into the blood of the bee, from whence it is removed by the *rectal glands* and discharged from the rectum. Samples of ejected liquid have been collected and tasted by A. I. Root[85] and others[86, 87] and all agree that the liquid was tasteless and only pure water.

If an explanation of the source of these droplets is desired, that given by Dadant,[88] in 1880, seems most logical and worthy of tentative

---

74 Bazin, Gilles Augustin. 1744. *Natural History of Bees.* 452 pp. London. (p. 278.)

75 Reaumur, Rene Antoine de. 1740. *Memoires pour Servir a l'Histoire des Insects.* 5:207-728. Paris.

76 Babaz, Jean-Marie. 1868. *La Cave des Apiculteurs.* Villefranche.

77 Dadant, C. P. 1927. Evaporation of honey. *Amer. Bee Jour.* 67:572.

78 Planta, A. von. 1886. Ueber die Zusammensetzung einiger Nectar-Arten. *Ztschr. Physiol. Chem.* 10:227-247.

79 Greiner, F. 1892. The change of nectar to honey. *Gleanings in Bee Culture* 20:644.

80 Hasty, E. E. 1901. Bees ejecting the water of nectar. *Amer. Bee Jour.* 41:648.

81 Brunnich, K. 1909. How does honey ripen? *Gleanings in Bee Culture* 37:396-398.

82 Brunnich, K. 1919. About the bee's honey. *Amer. Bee Jour.* 59:56-57.

83 Brunnich, K. 1924. Die Eindickung des Nektars bei der Honigbiene. *Ztschr. angew. Ent.* 10(2):448-457.

84 Brunnich, K. 1926. The fable of the ripening of honey by evaporation. *Amer. Bee Jour.* 66:226-227.

85 Root, E. R. 1909. (Editor's note.) *Gleanings in Bee Culture* 37:398.

86 Thompson, C. 1880. How bees remove the water from thin honey. *Gleanings in Bee Culture* 8:270-271.

87 Hall, F. W. 1909. The evaporation of water from nectar. *Gleanings in Bee Culture* 37:709.

88 Dadant, Charles. 1880. Comment les abeilles evaporentelles les nectar? *Bulletin d' Apiculture Suisse Romande* 2:22-24. Also: 1927. Trans. by Kent L. Pellett. *Amer. Bee Jour.* 67:572.

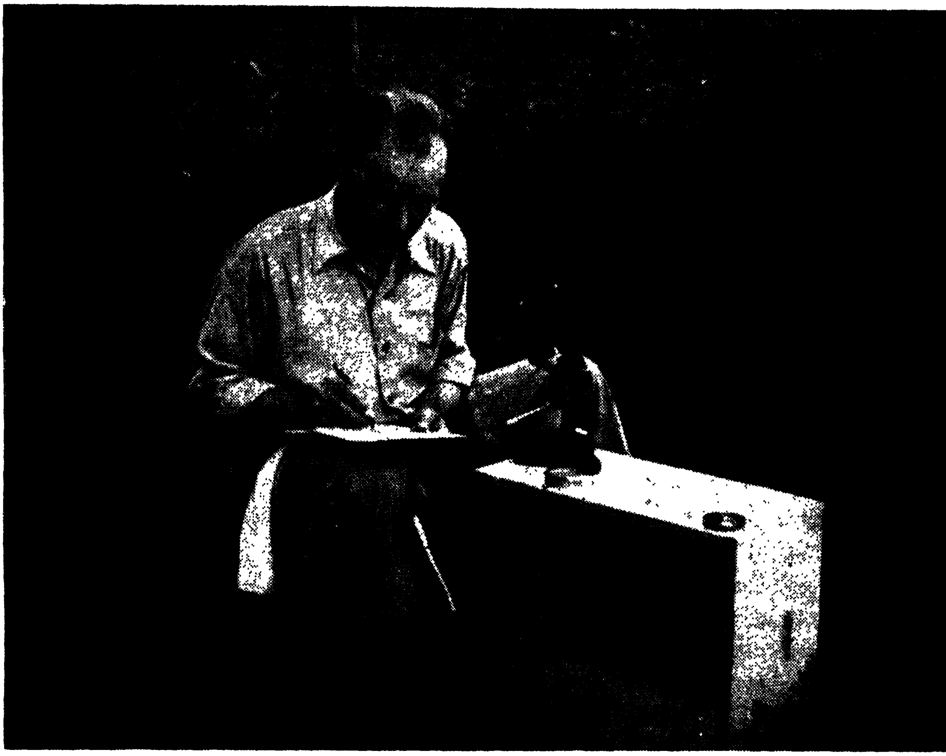


FIGURE 64. Laboratory facilities are not needed when using the Abbé refractometer. (*Photo by C. P. Wilsie*)

acceptance, at least. Calling attention to the fact that the "bee which works can live but a short time if it is deprived of nourishment," he contended, "It is then more rational to believe that the bees let fall only the water of the honey they digest, and that the evacuation* becomes visible when the nectar harvested contains so little sugar that it is necessary that those insects send into their stomach, a large quantity of it, to obtain the sugar indispensable for the restoration of their strength."

Fascinated by these presentations, the author in 1926, at the Iowa Experiment Station began a series of investigations in an attempt to find out whether the honey bee changes the concentration of nectar while en route to the hive. If so, is the change an increase or a decrease and to what extent? Other questions to be settled were: Does the change vary in direction or extent with the original concentration of the nectar? In case an increase is shown, is it sufficient to account for an appreciable thickening of the nectar?

Direct answers to these and related questions were obtained by comparing the sugar concentration of the honey-sack content of the bee en-

*Betts, Annie D. 1930. The ingestion of sirup by the honeybee. *Bee World* 11:85-90. (States that such droplets evidently come from the anus, as they contain bacteria and a little pollen.)

tering the hive with that of nectar or sirup taken directly from the same source from which the bee obtained her load. Results of the preliminary experiments conducted in 1926 (see reference No. 71), suggested that if any change occurs it probably is a decrease instead of the suggested increase in concentration. The use of colored nectar or sirup for the purpose of identification, and the Abbé refractometer[89] for making determinations on sugar concentration, developed during the course of the first two experiments, opened the way for conducting a third series of investigations (see reference No. 73) on a much larger scale and with more trustworthy results (Fig. 64).

By means of these researches it was learned that the honey bee changes the concentration of nectar or sirup only very slightly while en route to the hive, and that the change is a *decrease* instead of an increase as had been assumed heretofore. The amount of the decrease varies directly with the concentration of the nectar or sirup, the mean decrease varying from one-fiftieth of 1 per cent on a 13 per cent sirup to 1.8 per cent on a 64 per cent sirup. The average decrease for Iowa nectars commonly gathered by the honey bee is about 1 per cent. "Carry-over" from a previous load of different concentration is relatively unimportant, and changes in concentration of nectar or sirup while in the honey sack are not influenced by flight. For most practical purposes, it may be considered that the honey bee does not appreciably change the concentration of nectar while gathering a load and carrying it to the hive. Honey-sack contents of honey bees captured while gathering nectar from a given plant species give a close approximation to the actual concentration as found in those flowers. Such determinations open greatly enlarged possibilities for gaining new knowledge concerning sugar concentration in the nectar of plants.

Inasmuch as the results of this investigation have shown that no increase in sugar concentration occurs while the bee is en route to the hive with her load, it is certain that the expelled droplets bear no significant relation to the elimination of surplus water from nectar. And finally, the fact that bees carrying water *only* have been observed[90, 91] likewise to eject such droplets is in line with the conclusion that the excretion theory of honey ripening is untenable. Moreover, there is no longer any excuse for such a theory, for it has been shown that evaporation within the hive, in its several phases as reported herein, is entirely adequate to account for the observed rate at which fresh nectar normally is ripened into honey.

*Other Factors in the Ripening Process*

It is obvious that the rate at which water can be eliminated from fresh nectar and unripe honey is greatly influenced by a number of

[89]Park, O. W. 1929. The influence of humidity upon sugar concentration in the nectar of various plants. *Jour. Econ. Ent.* 22:534-544.

[90]Brooke, Jos. M. 1880. Are bees able to "strain" water from new honey? *Gleanings in Bee Culture* 8:318.

[91]Root, A. I. 1880. (Editor's note.) *Gleanings in Bee Culture* 8:318.

factors, other than those which have been discussed, which may be classified with respect to the beehive as *external* and *internal*. Under the former may be named weather and honeyflow conditions, while under the latter may be listed such items as colony strength, amount and concentration of nectar brought in per unit of time, extent of available storage cells, temperature, humidity, movement of air within the hive, and, last but not least, ventilation. Of these factors, only the last four will be considered further.

The rate at which evaporation takes place in the beehive varies directly with the temperature and inversely as the humidity, other things being equal. Movement of air strictly within the hive speeds up evaporation in proportion to the rate of movement, but at an ever decreasing rate as the air approaches its point of saturation for moisture. It is for this reason that there is need for an almost continuous exchange of air between the interior of the hive and the outside atmosphere, so that drier air from the outside may replace the moisture-laden air within. Whenever humidity is higher outside than inside, the action is reversed and honey in uncapped cells, in particular, absorbs moisture due to the hygroscopic properties of the sugars of honey.

*Humidity in the Beehive*—Theoretical aspects of humidity within the beehive have been ably presented by Phillips,[92] who pointed out the serious lack of information and the corresponding need for research on the subject. In 1923, Jessup[93] conducted a series of experiments on humidity within the bee colony. Having available no instruments suitable for recording the humidity among the bees, results were calculated from records obtained by a hygrothermograph located immediately above the colony. A colony of Italian bees, well above average strength, kept upon platform scales, was used throughout the experiment. Drainage of both water and air was poor as the apiary was situated on nearly level ground.

It was found that the relative humidity within the hive varied from a low of 20 to a high of 80 per cent; the lowest average recorded for one day was 30 per cent and the highest 65 per cent. Absolute humidity within the hive, however, tended to rise and fall with that of the atmosphere. Relative humidity within the hive was affected by the amount of nectar gathered and by the absolute humidity of the outside air. All maximum readings for relative humidity within the brood chamber occurred between 8 a.m. and 6 p.m., while 85 per cent of the minimum relative humidity records occurred between 3 a.m. and 6 a.m., which is just the reverse of relative humidity changes in the outside air.

*Rate of Ventilation*—In connection with his studies on humidity within the hive, Jessup[94] measured the rate at which bees by their fanning

[92]Phillips, E. F. 1924. Moisture within the beehive. *Gleanings in Bee Culture* **52**:17-20.
[93]Jessup, John G. 1924. *The humidity within the bee colony.* Unpublished thesis. Library, Iowa State College. Ames, Ia.
[94]Jessup, John G. 1925. Ventilation by the bee colony. *Iowa State Apiarist Rpt.* **1924**: 35-36.

are able to ventilate the hive. The work was conducted during a good honeyflow and, as the mean temperature for the period was 81° F., ventilation was essential to cool the hive and carry off the large amounts of water vapor from the abundant supply of fresh nectar. A special entrance, having two large circular openings equal in size to that of the regular entrance, was required in order to make use of a circular anemometer for recording the rate of ventilation.

From calculations based on weighings of the hive with and without bees, it was found that there were nearly 15 pounds or approximately 75,000 bees in the colony, as computed on the basis of 5,000 bees to the pound.* It is interesting to note that only about 10 pounds of bees were in the hive at 2:15 p.m. when the colony was shaken from its combs. The other 5 pounds later returned from the fields with their loads. From this it was assumed that for each bee that worked in the field, two were needed at the hive to look after the brood and the storing and ripening of honey, besides numerous other home duties.

Jessup states that the bees did not choose either of the two openings to serve continuously as intake or outlet, but changed the direction of the current from time to time. At times each opening served both as intake and outlet. Part of the time the direction of the air flow would remain the same for 10 to 12 hours; again the direction would be changed every half hour, or every 2 or 3 hours. No cause for such change was discovered. The rate of air travel varied from 189 to 312 feet per minute, with a mean of 256 feet for a 24-hour period. These figures, when translated into cubic feet of air moved per hour, are 489 for the minimum, 807 for the maximum, and 670 for the mean. Thus, on the average, the colony forced through the hive every hour more than enough air to fill a room 9 feet square and having an 8-foot ceiling.

The calculated loss of water during the 24-hour period was 5.7 pounds, or 50 per cent of the gross gain in weight. More than two-thirds of this loss occurred during the daytime. The fact that the interchange between inside and outside air took place more rapidly during the day than at night, coupled with the higher temperature and lower relative humidity during the day, caused Jessup to conclude that more evaporation of nectar takes place during the day than at night. This is contrary to the opinion held by some writers who have assumed that the fielders assist with the ripening during the night. The truth of the matter was pointed out at the turn of the last century by Astor,[95] a French authority on bees.

*It is stated that the 5 pounds of bees that returned after 2:15 were loaded. And it seems that those shaken off the combs had been smoked, so they, too, probably were far from empty. Under such circumstances, the number of bees in a pound usually is nearer 3,500 than 5,000. The latter figure is for bees that are practically empty (see references Nos. 54 and 55 in this chapter).

[95]Astor, Alex. 1901. Observations et expériences: Les poids des abeilles.—La quantité de nectar qu'elles peuvent rapporter.—L'évaporation du nectar et l'apport journalier d'une ruche d'observation sur bascule pendent la miellée de 1900. *Revue Internat. d'Apicult.* **23**:32-37.

The results of Jessup's investigation emphasize the need for providing ample ventilation, especially during hot weather. At such times, bees in hives with inadequate entrances often quit work and cluster on the outside of the hive for lack of ventilation.

*Ventilating to Facilitate Ripening*—Varying degrees of ventilation were provided in four normal colonies, as nearly alike otherwise as possible, by Reinhardt,[96] in 1938. In each of these he determined the daily rate of change in the concentration of unripe honey which had been freshly stored by the bees in clean empty combs during the course of a single afternoon. These combs were enclosed in individual screen cages to prevent the bees from removing the unripe honey or depositing more, and each was placed between combs of ripening honey in a super of one of the colonies.

Extra ventilation showed little, if any, effect on the rate of ripening during excessively hot and dry weather with only a moderate to light honeyflow. Nevertheless, this is no reason for ignoring other benefits of ventilation under similar circumstances, such as swarm control and the prevention of loafing and clustering outside during hot weather.

A comb of unripe honey in a hive with restricted ventilation failed to ripen within 21 days during a good honeyflow. In such a case the concentration of unripe honey may reach a state of equilibrium with certain environmental factors and fail to ripen so long as these conditions remain unchanged. Under such conditions, adequate ventilation should be helpful in speeding up the rate of ripening, unless the humidity of the outside atmosphere is as high as that within the hive when, of course, all evaporation would cease. Special ventilation was most effective when temperatures averaged around 80° F., when atmospheric humidity was relatively high, and when nectar was being brought in at a good rate. These experiments show that there really is a honey-ripening problem and a need for adequate ventilation.

## Time Factors

In 1920, and again in 1921, the writer made a study of the working habits of field bees collecting nectar (see reference No. 51 in this chapter). During the period of observation in 1920, average colonies stored about 5 pounds daily from white sweet clover (*Melilotus alba*), while in 1921, average colonies gained only a little over 1 pound daily from the same source. Weather conditions were highly favorable for honey production in the former instance, but were only fair in the latter. The data for field trips and hive stays of nectar carriers have been plotted as frequency curves (Figs. 65 and 66) in which the records obtained under favorable and unfavorable conditions are compared.

---

[96]Reinhardt, Joseph F. 1939. Ventilating the bee colony to facilitate the honey-ripening process. *Jour. Econ. Ent.* 32:654-660.

Under the favorable conditions of 1920, 31 per cent of the field trips lasted from 21 to 30 minutes, about 68 per cent required between 10 and 40 minutes, and 95 per cent occupied less than 1 hour. The mean time was about 34 minutes, but the time most frequently spent in the field was 27 minutes.

Under the unfavorable conditions of 1921, only 19 per cent of the field trips lasted from 41 to 50 minutes, about 48 per cent required from 30 to 60 minutes, and only 76 per cent were completed within 1 hour. The mean time for field trips was 49 minutes, but the most frequent interval was 45 minutes.

Inasmuch as the average speed of a fielder's flight was found to be approximately 15 miles per hour, it takes a bee about 4 minutes to go a mile. Estimating the average distance to the field as three-fourths of a mile during the favorable season, and as 1 mile during the less favorable one, the probable time required in going to and from the field was 6 minutes in 1920, and 8 minutes in 1921. The time spent in actual gathering, therefore, must have averaged about 21 minutes for 1920, and 37 for 1921.

As shown in Figure 66, nearly 40 per cent of the hive stays by nectar carriers lasted from 3 to 4 minutes in 1920, and over 75 per cent were completed within 10 minutes. The average time for all hive stays was 11½ minutes, but this figure is not significant owing to the markedly skewed form of the curve. The most frequent interval spent in the hive between field trips was 4 minutes. In 1921, hive stays were somewhat longer, about 23 per cent lasting from 5 to 6 minutes, but nearly 68 per cent being completed within 10 minutes. The mean time was about 16 minutes, while the most frequent interval was only 5½ minutes.

Thus the time required for a round trip was approximately 50 per cent greater during the unfavorable season of 1921, and this increase is

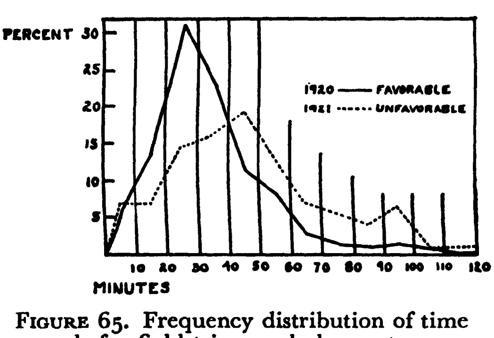



FIGURE 65. Frequency distribution of time records for field trips made by nectar carriers under *favorable* and *unfavorable* honeyflow conditions. (*Graph by the author*)

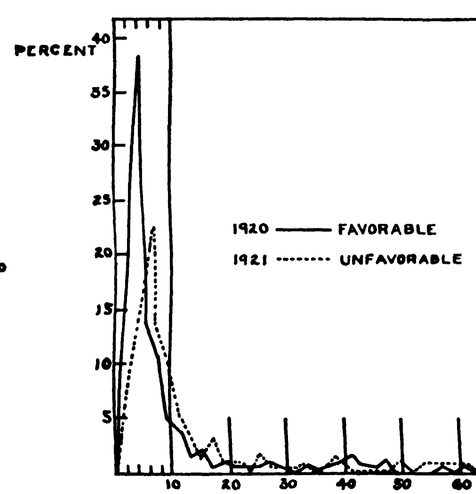



FIGURE 66. At right, frequency distribution of time records for hive stays made by nectar carriers under *favorable* and *unfavorable* conditions of honeyflow. (*Graph by the author*)

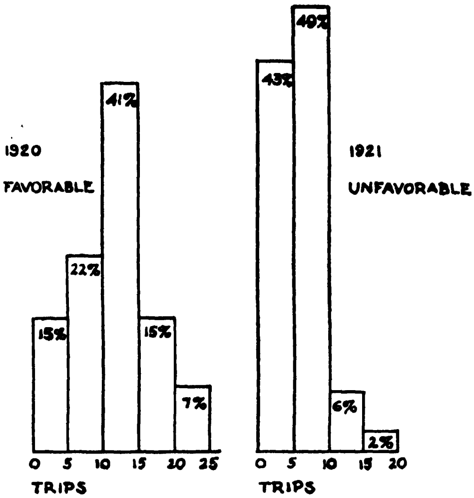



FIGURE 67. Frequency distribution of records showing trips per day for nectar carriers under *favorable* and *unfavorable* honeyflow conditions. (*Graph by the author*)

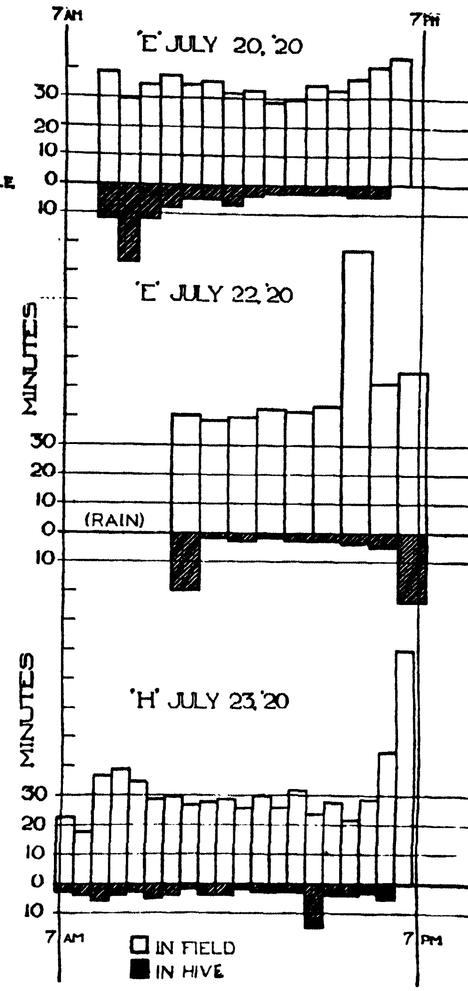



FIGURE 68. Illustrating the workday of individual nectar carriers under favorable conditions. (*Graph by the author*)

attributed largely to the greater difficulty experienced by bees in obtaining nectar during the poor honeyflow. This difference also is reflected in the number of trips made in a day (Fig. 67). The highest number of trips in one day for a nectar carrier was 24 in 1920, and 17 in 1921, the average number of trips being 13½ in 1920, but only 7 in 1921. If the mean time for round trips is multiplied by the average number of trips per day for the same season, it is found that the average working day for nectar gatherers was about 10 hours when conditions were favorable (Fig. 68), but only about 7½ hours when conditions were unfavorable.

Of the numerous reports that purport to give the number of trips made in a day by a nectar carrier—fantastic numbers running up to more than a hundred trips per day—only a few can be accepted with confidence.

One of the relatively few acceptable reports is that given by Heberle,[97] who cites the work of Luden. During a fair honeyflow from clover in 1914, Luden showed that nectar carriers made about 10 trips each day, each trip consuming about 30 minutes to 2 hours, with an average of about 1 hour per trip, and they remained in the hive from 5 to 10 minutes between trips. Lundie[98] made use of a mechanical device for counting all outgoing and incoming bees; thus distinction between trips for nectar and the many trips for other purposes was extremely problematical. Yet by selecting data obtained during honeyflow periods, it should be possible to secure averages that would be typical for conditions and the plant source involved.

It was found that, when gathering a light flow from black locust (*Robinia pseudo-acacia*), field trips averaged about 40 minutes. When gathering a heavier flow from tulip tree (*Liriodendron tulipifera*), the average duration of field trips during a 1-hour period on 1 day was only 12 minutes, although the average for 5 such periods was 22 minutes, and toward the end of the flow the average was 40 minutes. Lundie's records indicate that averages of 25 to 30 trips per day are sometimes made under *highly favorable* conditions, and that an average of 15 trips is to be expected during a good honeyflow.

Considering that weather conditions, honeyflow, and other factors have a great influence on the number of trips bees make in a day, the average of 15 trips determined by Lundie's data, Luden's figure of 10 trips, and the writer's averages of 13½ and 7 are in fairly close agreement. It is believed, therefore, that 10 trips per day probably is as reliable a general average as can be derived from the data at hand. For a more extensive review of the literature on this topic, the reader may consult the author's original publication (see reference No. 51 in this chapter).

## LABOR FACTORS

Large loads of nectar were found to weigh on the average about 70 milligrams, or 85 per cent of the weight of the bee which, in the case of Italians, was found to be approximately 82 milligrams (see references Nos. 54 and 55 in this chapter). Bees carrying ripe honey, as in a case of robbing, were found to have loads nearly equal to their own weight. Bees taken from a swarm as it issued from the hive carried loads that weighed three-fourths as much as their own bodies. Average loads of nectar during a honeyflow weighed about 40 milligrams, but the net weight of nectar delivered to the house bee from each collecting trip probably does not exceed 30 milligrams, because the field bee retains some nectar as fuel to provide power for her next outgoing trip. While the amount retained varies widely, 10 milligrams appears to be a fair estimate. Thus

[97]Heberle, J. A. 1914. How many trips to the field does a bee make in a day? *Gleanings in Bee Culture* 42:904-905.
[98]Lundie, A. E. 1925. The flight activities of the honeybee. *U.S. Dept. Agr. Bull.* 1328.

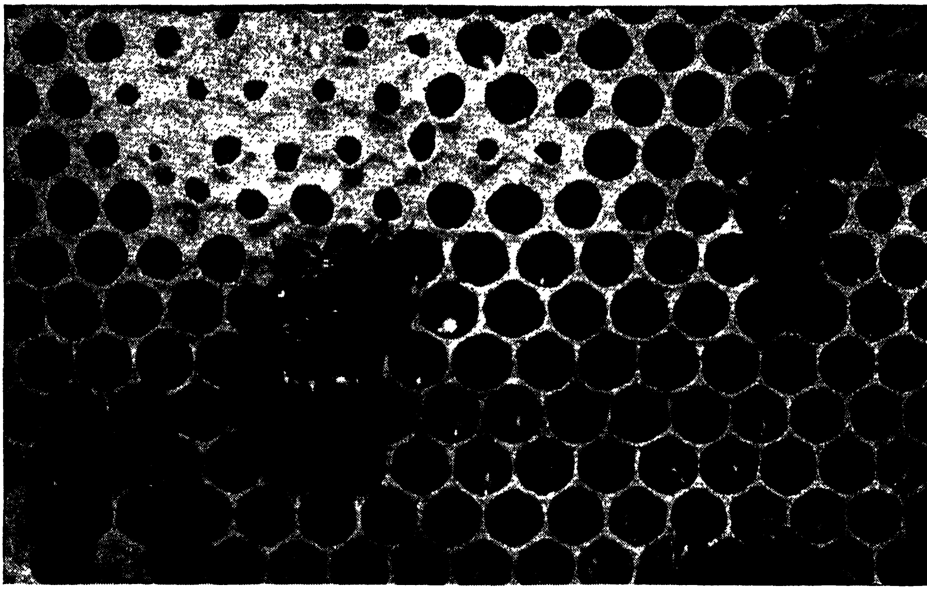


FIG. 68a. Newly stored honey being sealed in the cells of the honeycomb by the house bees. At bottom center are cells containing brood.

a nectar gatherer making 10 trips in a day would bring in about 300 milligrams of nectar. If she devoted herself exclusively to this task, she could gather and carry home about 6,000 milligrams, or 1/75 of a pound, of this essential raw material during the 20-day period, which is considered the normal expectancy for the term of field service for the average worker.

Having determined the percentage of sugar in thousands of samples of nectar, the writer can state that a sugar content of 40 per cent is quite common for nectar from the more important honey plants of Iowa. Assuming this figure to be representative, 2 pounds of nectar will be required to produce 1 pound of honey. Therefore, under favorable conditions a single bee would contribute about 1/150 of a pound of ripe honey to the colony's stores. It is unlikely, however, that *average* weather would permit uninterrupted field work for so long a period. Neither is it probable that the honeyflow would remain sufficiently favorable throughout a 20-day period to permit the rate of 10 loads per day to be maintained *on the average.* It seems probable, therefore, that during the course of her lifetime the average nectar gatherer may not contribute any more than 1/300 of a pound of honey.

As already mentioned, Jessup found two bees in the hive for every one in the field at 2 o'clock in the afternoon of a day when the colony under observation made a net gain of 8½ pounds. On the basis of 3,500 bees per pound* there must have been about 35,000 bees in the hive and 17,500 in the field. If it be assumed that all but 500 of the fielders were

*See footnote page 144.

engaged in gathering nectar and making 15 trips per day, the total number of nectar loads brought in that day must have been about 225,000. A further reasonable assumption is that the average sugar content of the nectar gathered was about 40 per cent and, if so, the total weight of nectar brought in was twice the net gain, or 17 pounds. This amount divided by 225,000, the total number of nectar loads, gives the average net weight of nectar loads delivered to the hive as 66 millionths of a pound, or 30 milligrams, the value reported by the author from earlier studies on the weight of bees and the loads they carry.

Root[99] states that a normal colony requires 200 pounds of honey for brood rearing in the northern United States. If in addition to its own food requirements, it produces 100 pounds of surplus honey for the beekeeper, a total of 600 pounds of nectar of 40 per cent concentration must be gathered and 300 pounds of water evaporated from it. The gathering would require the total field toil of 90,000 workers and perhaps twice that number of house bees to perform the work of ripening, the rearing of brood, and the various other household tasks.

If the honeyflow period is of 90 days' duration, as is normal in Iowa, the average colony would need to manufacture 3⅓ pounds of honey per day to produce a total of 300 pounds during the season. Scale-colony records covering a 25-year period at Ames, Iowa, show average net gains of 187 pounds for the 90-day period, or 2.1 pounds per day. By the time the beekeeper has taken his 100 pounds, only 87 are left to carry the colony from September 10 to June 10, a period of 9 months. It would appear, therefore, that the difference between 87 and the theoretical annual requirement of 200 pounds for the colony must represent the amount of honey consumed currently by the colony during the honeyflow period. If this assumption possesses a reasonable degree of accuracy, the average consumption of honey during the honeyflow period is 1/90 of 113 pounds, or a trifle over 1⅕ pounds per day, as against approximately ⅓ pound per day throughout the other 275 days of the year.

## Output

The output of our honey factory depends largely upon three factors: (1) Its numerical strength in laborers over 21 days of age, (2) the availability of nectar, and (3) the sugar concentration thereof. Extra-powerful colonies may possess 80,000 to 100,000 workers but 60,000 constitute a fine colony. In view of the findings of Jessup, Farrar,[100] and others, the obvious assumption here is that a colony having a population of 60,000 would be able to put into the field about 20,000 "hands" to work as foragers. Only in case the sugar content of incoming nectar is exception-

---

[99] Root, A. I., E. R., H. H., and M. J. Deyell. 1945. *The ABC and XYZ of Bee Culture.* p. 97. Medina, Ohio. A. I. Root Co.

[100] Farrar, C. L. 1926. Two-queen vs. single-queen colony management. *Gleanings in Bee Culture* 64:593-596.

ally high do bees engage actively in carrying water during a good honeyflow, inasmuch as their needs for that substance are amply supplied from the nectar. And while an abundance of pollen may be coming in at the time, a goodly proportion often results from its incidental collection by foragers that are gathering nectar primarily. At such times the proportion of fielders devoting their time exclusively, or even principally, to the collecting of either water or pollen usually is not great and for our present purpose may well be ignored.

Let it then be assumed: (1) That our honey factory is able to maintain a field force of 20,000 able-bodied hands (2) in an ample acreage of sweet clover that is yielding an abundance of nectar (3) containing on the average 40 per cent sugar. On a conservative basis calling for the delivery of 10 loads apiece, each weighing 30 milligrams net, 3,000 fielders could bring in enough nectar in a day to produce 1 pound of ripe honey. Then 20,000 could bring in enough for nearly 7 pounds of honey. Under the definitely favorable conditions stated above, however, an average of 15 loads per day might well be expected. Thus the hypothetical factory with 20,000 field hands could readily gather sufficient raw material to maintain a daily output of 10 pounds of the finished product.

Individual colonies of unusual strength occasionally make net gains of 20, 25, and even 30 pounds in a day, under exceptionally favorable conditions. Such gains of course are not achieved on more than 1 or 2 days in any one season, if at all! They are of interest mainly because they show what tremendous possibilities for honey production exist when the numerical peak of the field force in a well-managed apiary is attained coincidentally with the peak of a heavy honeyflow. A phenomenal gain of 33 pounds, for instance, can be accounted for satisfactorily enough as follows: A populous colony of 100,000 workers most certainly would have a field force* of not less than 33,000. By delivering 17 net loads apiece, of 40 milligrams per load, this force would bring into the hive a total of 22,440,000 milligrams, or 50 pounds of nectar. Assuming for the nectar a sugar concentration of 54 per cent,† the quantity indicated would be sufficient to produce 33⅓ pounds of ripe honey.

Experienced beekeepers in the North Central States, who are in territory having dependable bee pasturage, expect from each strong colony a daily output of from 5 to 15 pounds during the peak of the major honeyflow, together with lesser amounts over a more extended portion of the season. In the region just mentioned, an average output of less than

*According to Miller, C. C., 1901, Stray straws, *Gleanings in Bee Culture* **29**:502, investigations by Schachinger showed that when 20,000 bees stored ½ pound of honey, 30,000 stored 1½ pounds, and 40,000 stored 4 pounds. Thus it appears that the stronger the colony the greater the proportion of the population that goes to the field, and the smaller the proportion of the product used for current consumption. For this reason it seems likely that, in a colony of 100,000 workers, the field force may very well constitute more than a third of the total population.

†This figure is only slightly higher than the actual mean found by the author for nectar from white clover (*Trifolium repens*), under Iowa conditions over a period of years.

50 pounds of surplus for the season is looked upon as a crop failure, with a yield of 100 pounds being regarded as just a fair crop.

## A Pound of Honey

In conclusion, consider for a moment what a pound of honey represents in the way of bee life and bee labor. As already indicated, it is the author's considered judgment based upon extensive studies of the life and habits of the honey bee that, under average conditions, the entire field labor of approximately 300 bees is required to collect and transport to the hive enough nectar for the production of a single pound of honey.

This, however, represents merely the labor involved in bringing the raw material to the factory. At the hive young bees are engaged in ripening the nectar, manipulating it with their mouthparts, and fanning to ventilate the hive. Little information is available as to the number of bees which would be so engaged, but it seems reasonable to estimate that for every nectar gatherer there would be at least one house bee devoting most, if not all, of her time to evaporating excess water from nectar (see "Rate of Ventilation" in this chapter). This is only one of the two major phases of the honey-making process but it probably requires 99 per cent of all labor involved in transforming nectar into honey. The other phase, which consists in the splitting of the sucrose molecules into the monosaccharides, dextrose and levulose, apparently requires little if any special handling.

The evaporation of 1 pound of water requires 262 calories of heat at 95° F. which closely approximates brood-nest temperature. If it were necessary for the bees to supply this heat solely from the oxidation of sugar in their own bodies, about 1/6 pound of honey would be consumed in ripening every pound of honey made from nectar containing 40 per cent sugar. Fortunately, however, heat from the air and direct radiation from the sun supply a large measure of the heat required.

But a pound of honey represents still more. The entire process of brood rearing and maintenance of the colony from one honeyflow to the next, including the nonproductive generations that live during the fall, winter, and spring, must be considered as part of the cost of making honey. And for every pound of surplus honey harvested by the beekeeper, the bees have gathered and consumed at least two other pounds.

Of course no one bee ever lived long enough to gather more than an insignificant fraction of the nectar required for the manufacture of a pound of honey. But if that were possible, the bee would need to work all day long every day in the year for more than 8 years to accomplish the feat. And in so doing, she would have flown a distance equal to more than twice that around the earth at the equator.

# V. *The Honeycomb*

BY H. C. DADANT*

A STUDY of the construction of natural or virgin comb, built entirely by bees, and the behavior of bees in comb building provides a sound basis for understanding what constitutes good combs in the beehive. Good combs are a requisite to successful beekeeping because they provide the inner home where the colony is reared and where the two foods, honey and pollen, are stored. By co-ordinating the best beekeeping practices with the instincts of the bees, good combs are obtained for use in a modern beehive.

## Natural Comb

Natural comb is always built of pure beeswax. The wax employed usually is secreted fresh for the purpose by the worker bees and may be recognized by its light color. Darker wax, carried from older combs which have been discolored through use, sometimes is employed.

The construction of natural comb usually starts at or near the top of the abode, whether the abode be in a tree (Fig. 69), rock cavity, box, or beehive. Natural comb is built downward from the underside of a more or less horizontal surface. The attachment of the comb usually is extensive at the top and may embrace the ends, while the bottom and lower corners of the comb often hang free. The comb is heavily built at the point of attachment, the bases of the cells being an eighth of an inch or more in thickness in order to sustain the weight of the rest of the comb, the bees, brood, pollen, and honey. The thickness of the bases gradually diminishes for a distance of about 2 inches where the midrib becomes very thin throughout the remainder of the comb. At the bottom edge, natural comb diminishes to a V-edge of empty, shallow cells.

While there does not appear to be any system or organization in the comb-building process, construction ordinarily proceeds by building one rhomboid base on which two cell walls are started. This is followed by a second rhomboid base and two more cell walls, and later the third rhomboid base and the last two cell walls. Much of the comb is started and partly built before any of it is finished to full depth. A heavy rim of wax is constantly supplied around the outer rim of the cells, affording the

*Henry C. Dadant. Inventor of crimp-wired foundation and copartner of Dadant & Sons, manufacturers of bee supplies. Specialist in the study of comb building.

FIGURE 69. A colony in nature, not being able to find a hollow tree or other suitable abode, elects to build its combs in the branches of a tree. Lacking a true guide for starting the combs, they are wavy and irregular in shape. (*Photo by Alvard Bishop*)

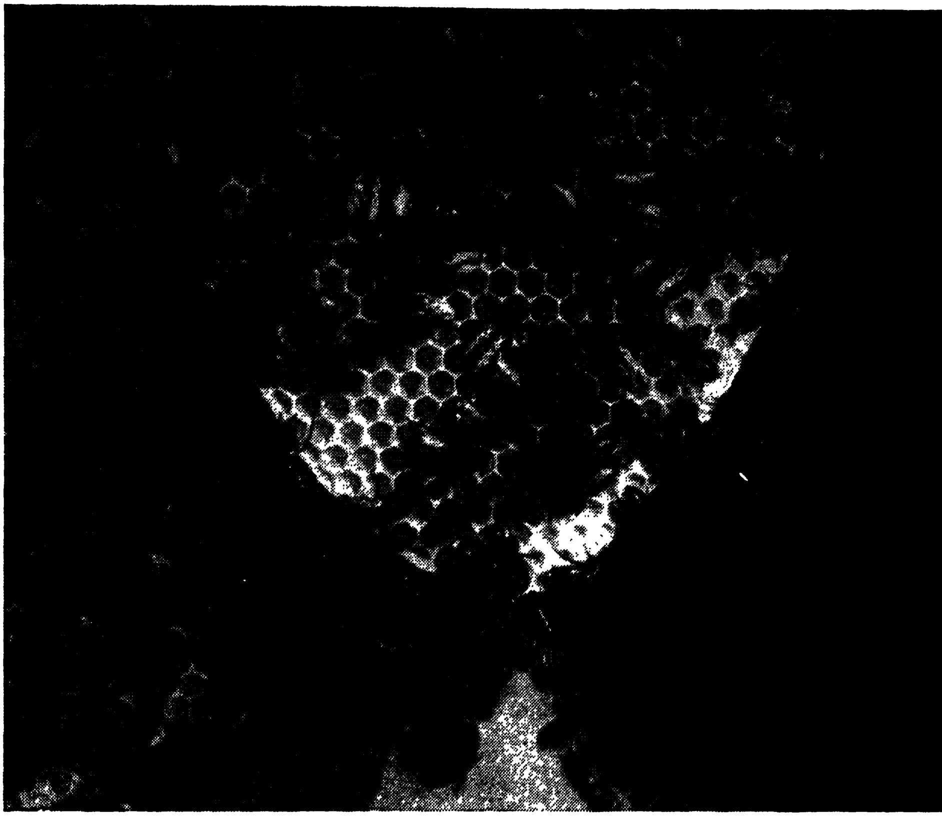


FIGURE 70. A natural U-shaped comb, with the worker bees building the cells and hanging in festoons while secreting beeswax.

bees a working supply of beeswax and protecting the fragile cell walls underneath.

Ordinarily, the thickness of the combs is about 1 inch and their distance apart, from center to center, is $1\frac{3}{8}$ to $1\frac{1}{2}$ inches, thus providing a passageway or bee space of about three-eighths of an inch between the combs. The surface of natural comb is seldom a true plane, nor are the rows of cells straight for more than a few inches. Variations are partly due to the lack of a true guide for their start at the top of the abode, and to irregularities in the walls. Because honey bees are social insects which work in groups during comb building, it is perhaps understandable how their apparent lack of co-ordination results in wavy and irregular combs.

Under normal conditions, more than one comb is started and, as the size of the colony grows and its prosperity increases, several more are begun. The combs usually are of a broad U-shape when first built (Fig. 70), obviating excessive weight on the upper part of the comb while it is still fragile. They are arranged side by side giving compactness to the colony for protection against invaders, such as robber bees and moths.

The number of combs, their size, and their shape depend on the space in which they are constructed, the season of the year, the strength of the colony, and the food at hand.

The prosperity afforded by a large honey crop induces the bees to fill their abode with combs, although some recesses are always found near the entrance. The combs of a colony often occupy several feet in a hollow tree or inside the walls of a building. In comparison to this, the space occupied by combs in a two-story Langstroth hive is about 3 cubic feet with a comb area of about 36 square feet on both sides of the combs. In a one and one-half story Modified Dadant hive, the space for combs and the comb area are about the same as the two-story Langstroth.

Certain comb constructions, known as brace and bridge combs, are constructed between the large combs or between them and parts of the abode. They possess some value for they serve as braces to hold the combs in position, as bridges for the bees in passing to other parts of the abode, and as temporary storage places for nectar during the honeyflow and for water in excessively hot weather. When plentiful, they may interfere with ventilation. Burr combs usually are built on flat surfaces of the abode and are burrlike in appearance. They may be the beginnings of bridge combs or they may be surplus beeswax secretions deposited in this way. The tendency to build these comb formations varies with individual colonies, as well as with strains of bees, some building very little.

## Secretion of Beeswax

The principal function of a normal swarm while hanging in a cluster is the secretion of beeswax. Beeswax is secreted from four pair of wax glands, one pair on each of the last four visible ventral segments of the worker bee (Fig. 71). It is contended that the conversion of nectar or honey into beeswax requires about 24 hours. For additional information concerning the secretion of beeswax and comb building, see Chapter IV, "Activities of Honey Bees."

Most apiarists before Huber's time supposed that beeswax was made from pollen, either in a crude or digested state. The great Swiss naturalist, Huber,[1] confined a swarm of bees without comb in a dark cool room and, at the end of 5 days, found that several combs had been built. When these were removed and the bees supplied with honey and water, new combs again were constructed. Seven times in succession the combs were removed and in each instance were constructed anew, the bees being prevented all the while from ranging the fields to supply themselves with nectar and pollen. By this and subsequent experiments, Huber proved that nectar and honey are the true sources of beeswax, and that sugar sirup answers the same purpose.

[1]Huber, Francis. 1926. *New Observations upon Bees*. (Trans. by C. P. Dadant.) Hamilton, Ill. American Bee Journal. pp. 115–122.

FIGURE 71. Wax scales extruding from between the wax plates and the abdominal segments of worker bees. Also some scales removed from the bees. Slightly enlarged.

Experiments by Baron von Berlepsch[2] showed that, during the construction of combs, bees deprived of pollen consumed from 16 to 19 pounds of honey in producing a pound of wax, while if provided with pollen the amount of honey was reduced to 10 to 12 pounds. When the experiment was continued for some time without pollen, the bees became exhausted and began to perish. It therefore appears that, although pollen is indispensable as a food to sustain the strength of bees during their work in comb building, little pollen, if any, is used in wax secretion. Experiments by Viallon[3] in Louisiana and by de Layens[4] in France showed that under favorable circumstances bees used only 7 pounds of honey in producing a pound of wax.

But the actual cost of combs cannot be reckoned solely by the amount of honey consumed by the bees. It must also be borne in mind that there is the loss of time in digesting the honey, as well as the time required in building the comb. And if the harvest is on, the bees may not be able to take advantage of it for lack of storage combs.

The first requisite for the secretion of beeswax is a stomach well filled with nectar or honey. It is an interesting fact that comb building and honey gathering proceed simultaneously and that when one stops the other stops also. As soon as the nectarflow slackens to a point where the consumption of nectar or honey exceeds the surplus, bees cease to build new combs even though large portions of their abode are unfilled. Langstroth has said: "When honey no longer abounds in the field, it is wisely ordered that they should not consume in comb building the treasure which may be needed for winter use."

There is evidence that the secretion of beeswax is involuntary during the honeyflow. But, although the amount of beeswax secreted may ex-

[2]Brunnich, K. 1923. Wax secretion. *Amer. Bee Jour.* **63**(1):75–76.

[3]Viallon, Paul L. 1885. Amount of honey consumed by bees to make one pound of beeswax. *Amer. Bee Jour.* **21**:153–154.

[4]de Layens, G. 1887. New experiments. (Trans. by W. P. Root.) *Gleanings in Bee Culture* **15**:171–172.

ceed that required for extending the cell walls and capping the cells of the combs, wax scales seldom are wasted in noticeable quantities about the hive. Usually bees secrete beeswax in proportion to their needs. A swarm responding to the necessity of building new combs has a supply of wax scales ready for the purpose. If hived on fully drawn combs, some of the wax scales may be wasted and wax secretion diminishes rapidly. If hived in an empty box or on full sheets of comb foundation, the bees immediately make use of the beeswax they are secreting and continue to secrete more until a sufficient number of combs have been constructed for use by the colony.

If the beekeeper is neglectful in providing room as needed during the honeyflow and if bees are instinctively responding to the nectarflow by secreting beeswax, it is not surprising to find them with more wax scales than they can use. An abundance of burr and brace combs built during the honeyflow is an indication of plentiful secretion of beeswax. If there is no storage space available, bees may cluster on the outside of the hive where lumps of wax scales can be found later, or they may build combs there for honey storage. At such times, a small oversupply of wax scales occasionally is found where the wax scales were dropped on the bottom board or the tops of frames.

If an abundant supply of nectar or honey is lacking, sugar sirup fed to bees will induce them to secrete beeswax. Small pieces of comb or shavings of beeswax placed in a pan over the brood nest promote comb build-

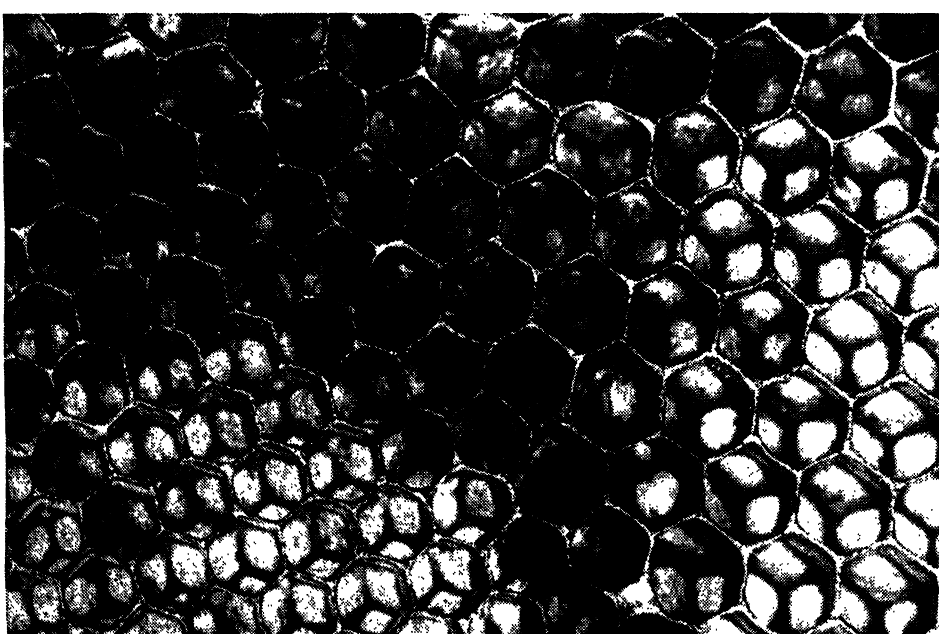


FIGURE 72. Worker- and drone-size cells showing many odd-shaped transition cells in between. Enlarged about 2X.

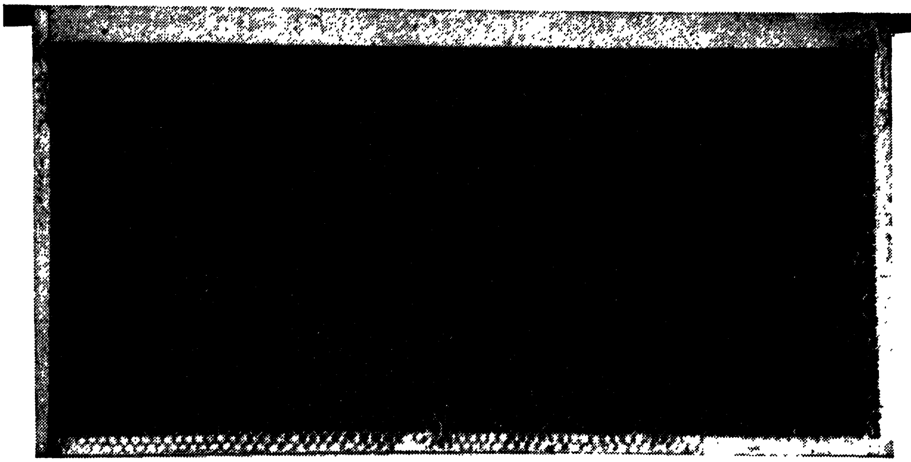


FIGURE 73. An excellent comb of worker-size cells fully utilizing the space within the frame, with scarcely a drone-size cell.

ing. Liquid beeswax painted lightly on comb foundation serves a similar purpose, but much comb building cannot be induced without an ample supply of nectar or honey.

## Comb Building

Combs consist of two distinct sizes of cells known as worker and drone, and these are of a size to accommodate the rearing of worker and drone bees. Accommodation cells, or odd-shaped cells, are found at the borders of combs while transition cells are built where a change from the worker-size to the drone-size cells occurs (Fig. 72).

Natural combs are a source of pure beeswax, yet their size and form usually are not suitable for profitable beekeeping practice. Colonies hived without comb foundation in the frames locate and build combs in a similar irregular manner as though occupying a plain box. Much of the value of a modern hive is lost if the frames are fitted only with starters or narrow strips of foundation. The use of full sheets of comb foundation, well reinforced in the frames, will prevent excessive drone comb, and will result in desirable straight worker combs that are easy to handle (Fig. 73).

The primary needs of a new colony are to increase its population and to provide ample stores of honey and pollen. An ample amount of combs consisting of worker-size cells from which to rear a greater working force first is built. This continues as long as the queen keeps all cells filled by her capacity to lay eggs. Apparently, when her laying capacity is accommodated by an ample supply of worker comb, drone comb then is built. The building of drone cells also is promoted by the instinct to swarm, particularly at the beginning of a good honeyflow, bringing with it a need for drones for mating with the new queen.

Drone comb may be found scattered throughout the combs in a hive and much of it may be used for storing of honey. There seems to be no regularity as to the position of the drone comb although much of it is outside or adjoining the principal worker-brood area. Considerable areas of drone comb have been observed near the top of brood frames. This does not indicate a normal position but usually proves that the cells at that point became enlarged by a downward stretching due to lack of sufficient reinforcement of the honeycomb base. A colony of bees building under its own inclination without comb foundation constructs from one-sixth to one-fourth drone cells. The rearing of drones in honey-producing colonies is to be avoided as much as possible because drones do not gather nectar nor do any work inside the hive, but only consume honey.

Some drone cells will always be built, particularly at the margins of combs. Bees will seize every opportunity offered them to reconstruct stretched cells and will rear drones in them. Some drone comb has been found built over worker-size cell bases, but this is rare. The quantity of drone comb, with proper care, can be held to about 5 per cent exclusive of the edges of combs. Combs containing more drone comb than this should never be used for brood rearing, but should be used in supers for honey storage or be discarded.

Supplying full sheets of comb foundation will not always insure the best combs. Conditions favorable to comb building must also exist. Previous to the main honeyflow, when brood rearing should be proceeding without interruption and when comb building is necessary, ample feeding of sugar sirup often is resorted to for satisfactory wax secretion. Otherwise, comb foundation, whether in brood frames or in extracting supers, may be damaged beyond repair. Bees may tear down unoccupied foundation to employ the wax on combs already in use. In extreme cases, they may secure needed wax by gnawing unoccupied drawn comb. Sometimes, they appear to damage good combs or build undesirable ones as if in pure mischief.

At the time the combs are being drawn out from full sheets of comb foundation, the frames should not be spaced farther apart than 1½ inches from center to center. When fully drawn, it is common practice to space super combs as much as 1¾ inches center to center, resulting in thick combs of honey which facilitate uncapping and extracting.

Combs drawn from foundation in the brood nest often do not extend to the bottom bars, particularly near the entrance, thus providing space for ventilation. When a space of an inch or more is provided between the floor of the bottom board and the bottom bars of the frames, the bees are more likely to extend the combs to the bottom bars, the same as they build full combs in the supers.

If not reinforced by the best methods, combs may stretch or sag downward in hot weather, resulting in considerable distortion. As much as 50 per cent of the total comb area may become unfit for the rearing of

worker bees. Because this is a serious handicap to the progress of colony strength, the wise beekeeper takes precautions to see that all combs are well built of worker cells, and amply reinforced with wires to preserve their shape. Combs that are broken, wavy, or misshapen from various causes should be melted up. There is little loss sustained by the beekeeper because the comb contains about twice the quantity of beeswax required for a sheet of comb foundation.

About 5 to 10 per cent of the combs can be replaced profitably each year, even though they have been properly reinforced and originally built under favorable conditions. Fifty per cent or more of the combs in many old hives that have not received proper attention should be culled. If poor combs are replaced with frames containing full sheets of foundation with the best system of vertical and horizontal wiring, the amount of comb culling from year to year will be reduced. The result obviously will be an increase in worker bees that produce the crop with a reduction in drones that are detrimental to a maximum crop.

During spring and early summer, the tendency of a normal colony to build comb is very dominant. Comb may be partly drawn on comb foundation even though the food supply is not sufficient for the secretion of new wax. The bees thin down the bases of the cells of the foundation and draw out the cell walls as far as available wax will permit. Medium brood foundation contains enough beeswax in the cell bases and partial cell walls to enable the bees to produce at least half the depth of the finished comb by their thinning process. Because of the initial cost, some beekeepers prefer to use the thinner, light brood foundation. During the honeyflow, increased wax secretion will enable the bees to build combs on light brood foundation as readily as they will on medium brood foundation. However, in normal beekeeping practice, the use of medium brood foundation will be found best because of the time and honey consumed by the bees in wax secretion (see Chapter IX).

## Size of Cell

It is obvious that worker cells are of a size and shape which will accommodate comfortably the mature larvae and permit the entrance of the adult worker bee and the queen. Worker bees enter cells head first while feeding larvae, storing and removing honey and pollen, and when cleaning and varnishing the cells. The abdomen of the queen, which is inserted to the bottom of the cell in egg laying, is approximately the size of the entire worker bee.

Bees have refused to use comb foundation having cell bases measuring a few thousandths of an inch less than those naturally built, but they will readily accept cells that are slightly larger than normal. However, bees of different colonies of the same race construct cells of practically the same average dimensions.

Races of bees such as the Italian, Carniolan, and Caucasian build cells of practically identical size, and accept standard comb foundation readily. Standard comb foundation usually is made on dies providing 857 cells per square decimeter, but the resulting cells may vary from this and usually are larger due to stretching of the wax in manufacture. The native-German black bees, according to European records, build smaller cells.

The small bees of India and other countries of the Far East possess the ability to survive the attacks of insect enemies and a climate that our bees find difficult to meet. The former are therefore cultivated by man in their native lands in preference to the races of *Apis mellifera*. The bees of *Apis indica* races build comb with cells of quite small size which accommodate their needs. The larger, vicious bee, *Apis dorsata,* of the Far East, on the other hand, defies cultivation. The cells of their worker comb are distinctly larger than all other honey bees.

TABLE I. Approximate Number of Cells on Both Sides of the Comb, Worker Size

| *Race of Bees* | *Cells per Square Decimeter* | *Cells per Square Inch* |
|---|---|---|
| Italian | 857 | 55.3 |
| Caucasian | 857 | 55.3 |
| Carniolan | 857 | 55.3 |
| Italian (Drone) | 520 | 33.5 |
| Native German | 897 | 57.9 |
| *Apis indica* | 1243 | 80.0 |
| *Apis dorsata* | 787 | 50.8 |

Cells of natural comb vary in size due to curved rows of cells, transition from the worker- to the drone-size cells, and abnormalities toward the edges of combs. By taking measurements along rows of hexagons, side by side, sealed worker brood has been found to vary from five cells measuring 1 1/32 inches to 1⅛ inches along a few odd rows of cells built in spreading or fan-shaped directions. Since the most reliable measurements are obtained from regularly built and compact brood areas, abnormal cells should not be included.

Not only do the cells vary in size but the angular measurements of their bases also are not exactly the same. By filling pieces of comb with plaster of Paris, accurate cross sections can be obtained. The average of the right angle cross sections of two adjoining bases is about 120°. It has been mathematically and geometrically proved that the greatest economy in wax results from this construction. This was recorded by Huber who found that others had preceded him in this determination. Frequently there is a variation of 3° to 5° in this angle. Cell bases having an angle of 120° are larger than those having greater angles, and when the comb is finished the cell walls are shorter.

While combs are built vertically, or practically so, the cells are not built at a right angle to the vertical but slope upward from the central

plane of the base (Fig. 74). The angle of the upward slope varies from 9° to 14°. This sloping apparently tends to prevent the larvae from sliding out the mouth of the cells before they are sealed and to aid in containing the food placed there by the worker bees.

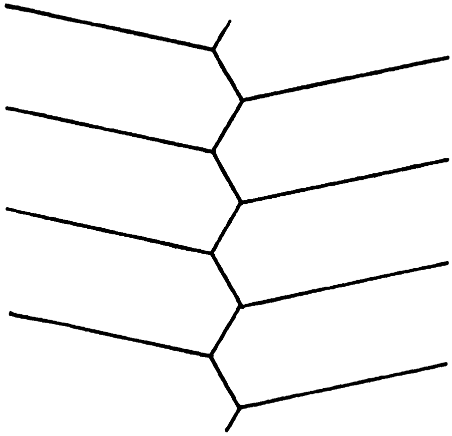


FIGURE 74. Diagram of vertical section of the honeycomb showing the midrib with the cells extending from both sides at a slight upward angle.

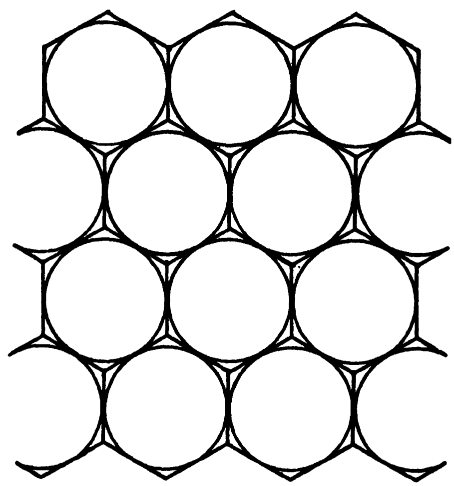


FIGURE 75. Diagram of adjoining hexagons with adjoining circles inscribed within them, showing that the adjoining hexagons provide for economical division of space.

## The Shape of the Cell

The cell of the honeycomb is a hexagonal-shaped tube, consisting of six walls each of which forms a proportionate part of another cell, closed at its base by three rhomboids which form an inverted pyramid. Each of the three rhomboids forms a third of the base of a cell on the opposite side of the comb.

A study of the hexagon, the triangle, and the square reveals that these geometrical shapes can be fitted together without waste of space. Neither the pentagon, the heptagon, the octagon, or the circle provides continuous and economical division of space. Since the queen's abdomen is virtually round, a group of adjoining circles would seem to be best. The diagram shows that a group of adjoining circles fits inside a group of adjoining hexagons (Fig. 75). If circles of flexible material are forced together under pressure, they become hexagons. Likewise, a group of adjoining cylinders with conical ends, fitted together under pressure, forms bases similar to those constructed by bees. Thus, the hexagon provides for an economical division of space and best accommodates the abdomen of the queen bee.

## Comb Measurements

Measurements are most accurately made with a micrometer having points about one-sixteenth of an inch or less in diameter. The points should be applied to the center of the part which is being measured. If this is done in zero weather, while the wax is hard and the instrument cold, the full thickness will be recorded.

Measurements of new natural comb, built entirely by the bees, reveal that the central or thinnest part of walls and bases are about double the thickness of fine tissue paper, which is 0.001 to 0.002 of an inch in thickness. The average of cell walls measure about 0.001 of an inch thinner than the bases. This may be due to the fact that the bases are smaller and most difficult to build thin.

TABLE 2. Average Thickness of Cell Bases and Walls, in Inches, Before and After Comb Foundation is Drawn Out

| *Natural Comb* | | *Brood Foundation* | | *Surplus Foundation* | |
|---|---|---|---|---|---|
| | | *Before* | *After* | *Before* | *After* |
| Cell bases | 0.0035 | 0.025 | 0.008 | 0.011 | 0.005 |
| Cell walls | 0.0025 | | 0.0025 | | 0.0025 |

The figures in Table 2 indicate that when comb is built on comb foundation the cell bases are always thicker than natural comb, whereas the cell walls are identical in their thickness in all cases. This is no doubt due to the ease with which the two mandibles of the bees can be applied, one on each side of a cell wall like a pair of scrapers. The mandibles are not as suitable for scraping the flat surfaces of the cell base, and the thinning of the base is a slow and laborious process. The only times that bees do not thin the cell bases of comb foundation appreciably are when a heavy honeyflow results in excessive work for the house bees, when there is a shortage of house bees, or when the temperature of the colony is below normal. When this happens, the cells may be worked over at another time and the cell bases made thinner.

## Reduction in Cell Size

Brood cells become reduced in size with use and age. There is a slight thickening of the cell walls and bases due to the accumulation of cocoons and cast-off larval and pupal skins, and to the treatment given the cell in preparation for the next cycle of brood. However, it has been observed that the thickening due to this accumulation is principally in the base of the cells and that over a period of years, bees thin down the cell walls and extend them to compensate for this. The corners of the hexagonal cell appear to be gradually rounded. No objection to the rounded cell has been noted, although reduction in the size of the cell may render combs less suitable for brood rearing.

It would require the thickening of the cell walls only 0.004 to 0.005 inch in order to reduce the normal cells of the Italian bees to the size built by the smaller German or black bees. Michailov[5] has shown that after 16 to 18 generations the diameter of the cells is reduced 5.89 per cent and that this reduction caused a significant reduction in five physical characters of the exoskeleton.

Beekeepers frequently have reported that combs have been in use 20 to 30 years with no noticeable reduction in the size of the bees. It is probable that the thinning down of the cell walls and their extension, plus variation in cell size due to the downward stretching or sagging of combs and due to faulty making of foundation, may compensate for the thickening of the cell walls over many years.

## Large Cell Controversy

Investigators in Europe have advanced the idea that worker bees reared in large-size cells were larger; possessing an increase in tongue length, wing size, and nectar-carrying capacity. They further claimed that a greater crop per colony was obtained by these bees in comparison with that obtained by bees in the same apiary reared in normal cells. They experimented with comb foundation having 760, 700, and 640 cells per sq. dec. (49.0, 45.2, and 41.3 cells per sq. in.) and their contentions resulted in foundation having larger cell bases being marketed in Belgium and France since the beginning of the century.

A study[6] of the influence of size of brood cell upon the size and variability of the worker bee, using foundation having 857, 763, and 706 cells per sq. dec. (55.3, 49.2 and 45.5 cells per sq. in.), showed that the size of the worker bee is affected and that significantly larger bees are obtained. But the excessive claims of Baudoux,[7] of Belgium, were not substantiated. Baudoux had reported an increase in tongue reach of 11.9 to 25 per cent as compared to a maximum increase of only 2.07 per cent obtained by Grout. The increase in tongue length, accompanied by a corresponding increase in the dry weight of the bee and the size of wing, as determined by Grout, corresponded with data obtained by Michailov.[8]

Whether the increases in the measurements of the worker bees are significantly related to honey production has not been proved scientifically. However, the use of large-cell foundation for many years in the Dadant apiaries at Hamilton, Illinois, has shown nothing significant either for or against its use as a factor in increasing honey production.

[5]Michailov, A. S. 1927. Variability of bees and their combs. (Trans. title.) *Opitnaja Paseca.* pp. 246–249.

[6]Grout, Roy A. 1937. The influence of size of brood cell upon the size and variability of the honeybee (*Apis mellifera* L.). *Iowa Agr. Exp. Sta. Research Bull.* 218.

[7]Baudoux, Ursmar. 1927. Agrandissement des abeilles. *L'Apiculture Rationelle* 11:57–58.

[8]Michailov, A. S. 1927. Workers of *Apis mellifera* reared in drone cells. (Trans. title.) *Rev. Russe. Ent.* 21:151–162.

FIGURE 75a. The honeycomb serves for the rearing of brood as well as for storage of food—pollen and honey. Here the worker bees are occupying an area of worker brood while some, with their heads in the cells, are taking up a load of honey, inasmuch as they have been disturbed by the taking of the picture. (*Photo by Ben Knutson*)

# VI. *Beekeeping Equipment*

BY H. C. DADANT*

IT IS a rather remarkable fact that many valuable discoveries concerning the life history and activities of honey bees were made before the development of modern methods and equipment. The records of early observers indicate that they realized that many mysteries of the honeybee colony needed to be solved before further progress could be made. Their research enabled others who followed to devise commercial methods of rearing queens and package bees as well as producing honey and beeswax.

Although the beehive of today was invented about the middle of the nineteenth century, this great improvement was not an entirely new concept. Hives of similar shape with rectangular movable frames invented by Huber and others had been in use many years. Although comparatively inconvenient, they permitted those who were absorbed with research some movement of the combs and inspection of the bees. This made possible valuable discoveries and corrected many erroneous claims and assumptions concerning bees.

Almost a hundred years have passed since the modern hive came into use, yet hobbyists, side-liners, and commercial beekeepers continue to discover interesting new facts and to rediscover old ones. The behavior of bees has probably proved more interesting to man than the production of honey and beeswax, although the sweetness and flavor of honey no doubt promoted his first attraction to them.

Through the use of modern equipment, the beekeeper is now the master while formerly it was the bees. It is no longer necessary to endure loss of time and crop by breaking into receptacles containing bees, cutting the combs away with a knife, and guessing at the condition of colonies. On the contrary, every colony can be well judged and controlled. A good honey crop can be readily harvested during a season of abundant nectar supply, but no one can make a success from year to year without knowledge of the behavior of honey bees, proper and timely attention to the colonies, and the use and efficient manipulation of modern beekeeping equipment.†

*Henry C. Dadant. Inventor of crimp-wired foundation and copartner of Dadant & Sons, manufacturers of bee supplies. Specialist in the study of comb building.

†The author of this chapter has drawn freely from Chapter X, "Beehives and Beekeeping Equipment," by M. G. Dadant, in the first edition of this book. For the use of this material, due acknowledgment is gladly given.

## Early Beehives

The early hives or abodes (Fig. 76) provided for bees would all be classed today as inconvenient, undesirable, and even uneconomical although low in first cost. They were as crude as the natural abodes of honey bees, such as a hollow log or a rock cavity. The "bee gum," so called because it often was made from the gum tree, was a hollow log. Two sticks crossed at the top supported the combs, a rough board covered the top, and a notch in the bottom served as an entrance. The box hive was a manufactured hive, but was shaped like a box instead of a hollow log.

In the Old World, straw or willow skeps and pottery hives were common. The earthen hive was simply a tube laid on its side and closed at each end with wooden disks. One disk was removed to take the honey, which was always located at the back of the hive.

To take the honey from these early hives, it was the practice to drive the bees into another hive, and then to remove all of the combs. Even today in some European countries, the contents of similar hives are sold to concerns that are equipped to remove all of the combs and to separate the honey from the beeswax.

Later hives were divided into several horizontal sections. When the upper story was full of honey, a wire was used to cut the combs between the sections and an empty section was placed under the full one. In 1634, Butler described hives consisting of four sections piled one upon another.


FIGURE 76. The evolution of the modern beehive. From left to right are: the straw skep, the "bee gum" or log hive, two types of box hives, and a modern beehive equipped with a pollen trap at its entrance. (*Photo courtesy J. C. Hudson*)

In 1750, Palteau advised beekeepers to use a perforated ceiling at the top of each section. Toward the middle of the nineteenth century, Oettl made a straw hive which was divided into three vertical parts.

The beekeepers of Greece[1] appear to have been the first to improve their hives with movable bars from which combs were suspended by the bees. About 1789, Francis Huber provided a frame which supported the combs on all sides (Fig. 77). Instead of hanging the frames inside of the hive, Huber fastened them together at the back with hinges enabling them to be spread apart in front like the leaves of a book. Because of this, Huber's hive became known as the "leaf hive" and consisted of twelve frames about 12 inches high, 10 inches deep, and 1¼ inches wide.

Several attempts were made in the first half of the nineteenth century to make practical hanging-frame hives. In 1821, Radouan used triangular bars to support the combs. In 1838, Dr. John Dzierzon, of Germany, revived the Greek type of hive and improved it. Because his hive opened from the back, it was necessary to cut loose all of the combs in order to remove the one at the front of the hive. Notwithstanding this difficulty, Dzierzon's hive gave a new impulse to the cultivation of bees. C. J. H. Gravenhorst, also a German, designed a movable-frame hive made of straw. The frames were removed from the bottom and there was no separate compartment for honey. In 1845, Charles Soria used bars at the bottom of each section as well as at the top, with a space between so that the sections could be removed, exchanged, or reversed without crushing the bees or damaging the combs. Other attempts to make a practical hanging-frame hive included those of Prokopovitsch in Russia, Munn in England and Debeauvoys in France, but their attempts were without marked success.

Similar in its frame spacing to the Langstroth hive, was a hive invented by Baron von Berlepsch, in 1853, which contained two sections for brood rearing and one for storage of surplus honey. Because the hive opened at the back, it was necessary to remove all the combs in each section to examine the last one.

The development of modern beekeeping in the Old World has been greatly handicapped by lack of standardization and the continued use of many different sizes of small hives, often with the entire lack of movable combs. Even as late as 1948, a dealer in beekeepers' supplies in Portugal attempted to secure comb foundation for ten different sizes of hives used in his country.

## Development of the Beehive in This Country

Prior to 1853, bees were kept in boxes or other crude devices. Demuth[2] designated this period as the *Box-Hive Era*. Later as beekeepers noticed

[1]Wheler, George. 1682. *A Journey Into Greece*. London.
[2]Demuth, G. S. 1935. The evolution of beekeeping practice. *Amer. Bee Jour.* 75:30-32.

FIGURE 77. Francis Huber, the blind Swiss, who contributed greatly to our knowledge of bee behavior, and invented the leaf hive that enabled him to make many of his discoveries.

that bees placed their stores above the brood, a cap or upper story was added. This was usually a box inverted over a hole in the top of the box hive. The period from 1853 to 1867, therefore, is called the *Box-Honey Era*. It was during this period that three fundamental inventions took

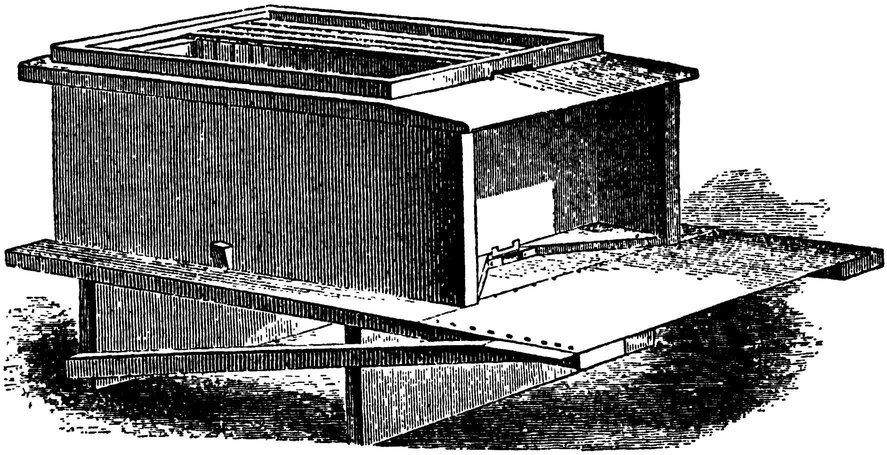


FIGURE 78. The original Langstroth hive, the first top-opening, movable-frame hive that provided a bee space between frames and other hive parts, which made possible the present extent of beekeeping.

place which were to greatly influence the advancement of beekeeping: the movable-comb top-opening hive, comb foundation, and the honey extractor.

In 1851, Langstroth discovered the bee space and invented his movable-comb hive (Fig. 78) and, in 1853, he published his book which gave a detailed description of its management. The frames were constructed so that they could be suspended in the hive, leaving a space of one-fourth to three-eighths inch, called a bee space, between all surfaces, permitting combs to be removed without crushing the bees. Additional bodies for rearing brood or for the storage of surplus honey could be added on top and removed easily. The principles of his hive are incorporated in all modern hives.

About 1843, Gottlieb Kretchmer[3] produced a comb base and Johannes Mehring made comb foundation on a flat press in 1857. Then, in 1865, Franz von Hruschka invented the honey extractor. Comb foundation and crude homemade extractors soon were in use making it possible to produce quantities of honey and remove it from the combs. Thus the period, 1867 to 1876, is known as the *First Extracted Honey Era.*

With the bee journals beginning to disseminate information, the first controversies on the size of the frame and the size of the hive began. J. S. Harbison of California, had introduced the four-piece honey section in 1857, and a marked trend toward the Langstroth frame and a smaller brood nest followed. In 1883, G. M. Doolittle reduced the Gallup hive to nine frames, 11¼ inches square, and then to six frames. By 1885, Heddon and others reduced the Langstroth ten frames to eight, and even to five frames by the use of two "dummies" which occupied the space of

[3]Kretchmer, E. 1878. Comb foundation. *Amer. Bee Jour.* 14:427-428.

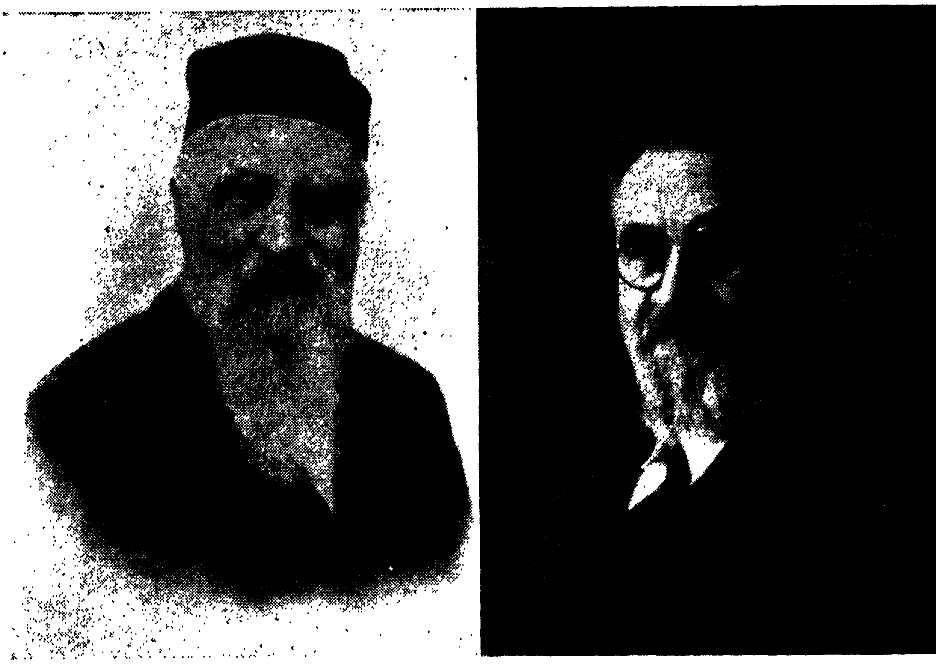


FIGURE 79. Charles Dadant (left) and his son, C. P. Dadant (right), recognized leaders in beekeeping throughout the world, and originators of the larger Dadant hive.

three frames. Others contended that the brood nest should be divided horizontally, and the Bingham, Danzenbaker, and Heddon hives resulted. This period of contraction of the brood nest, 1876 to 1906, is known as the *Comb Honey Era,* and resulted in materially reduced crops of honey.

Foremost among the defenders of large hives were Charles Dadant and C. P. Dadant (Fig. 79). After lengthy experiments with hives containing eight, ten, eleven, and up to twenty frames, the original Dadant hive was adopted (Fig. 80). It was on the Langstroth principle but contained eleven frames of the Quinby size, having an inside dimension of 10 by 17⅞ inches. In his contention for the large brood nest, C. P. Dadant often quoted Langstroth[4] who wrote: "Many hives cannot hold one quarter of the bees, combs, and honey which, in a good season, may be found in my large hives; while their owners wonder that they obtain so little profit from their bees."

The writings of the two Dadants in English, French, and Italian bee journals and the French, Italian, Russian, Spanish, and Polish translations of their revisions of Langstroth's book greatly influenced the establishing of the Langstroth system of beekeeping and the adoption of the Dadant hive in those countries. The lack of German translations and the prestige of early German leaders no doubt precluded the spread of this

[4]Langstroth, L. L. 1883. *A Practical Treatise on the Hive and the Honey-Bee.* 4th ed. Philadelphia, Pa. J. B. Lippincott & Co. p. 329.

system in Germany, but the Dadant hive generally is standard in continental Europe.

In England, hives on the Langstroth plan but with frames having dimensions of 8½ by 14 inches have been in general use. In recent years, the 10-frame Langstroth and Modified Dadant hives have been adopted as standard, particularly by commercial beekeepers. Manley[5] emphasizes both, but expresses preference for the larger hive. He wisely adds: "But it must not be expected that success with these larger hives can be achieved unless bees of the highest excellence are used in them, as must always be the case if bee-farming is to be a successful venture."

The passage of the Pure Food Law, in 1906, making it possible to sell liquid honey without its purity being questioned gave a new impetus to the production of extracted honey. Demuth[6] marked the beginning of the *Second Extracted Honey Era* with the year 1906.

Although highly efficient, the original Dadant hive (Fig. 80) did not become popular in America due to its high cost, heavy weight, and odd size. Pellett and others encouraged the Dadants to produce a large hive of economic construction similar to the 10-frame Langstroth hive, hence the Modified Dadant hive was brought out in 1920. It is the same length as the Langstroth hive but contains eleven frames of the Quinby depth, spaced 1½ inches apart. This makes it possible to use Langstroth bodies on it as supers, although the 6⅝ inch Dadant super usually is used. It completes the large-hive idea of a large brood nest with shallow supers.

## Modern Hives and Hive Parts

The beekeepers of America are fortunate in that only two sizes of hives are in general use: the ten-frame Langstroth and the Modified Dadant hive. In fact, the two standard hives have not been superseded after many years of use, and methods of management that insure success have been adopted in each case. Each type can be adapted to accommodate larger colonies of bees and greater crops of honey.

The important contributions to the improvement and production of modern hives are largely shared by a few individuals who became manufacturers of beekeepers' supplies. A. I. Root was the most energetic in developing methods for large scale production of hives and other beekeeping equipment, although his efforts to popularize small hives and odd-size equipment largely failed. The Dadants were conservative and contributed fully proved, effective, and simplified equipment: the large hive and crimp-wired foundation. The G. B. Lewis Company served the industry by leading in the production of the one-piece section and in making many improvements in hives and hive parts.

---

[5]Manley, R. O. B. 1936. *Honey Production in the British Isles*. London. The Crown Press.

[6]Demuth, George S. 1935. The evolution of beekeeping practice, part II. *Amer. Bee Jour.* 75:115-117.

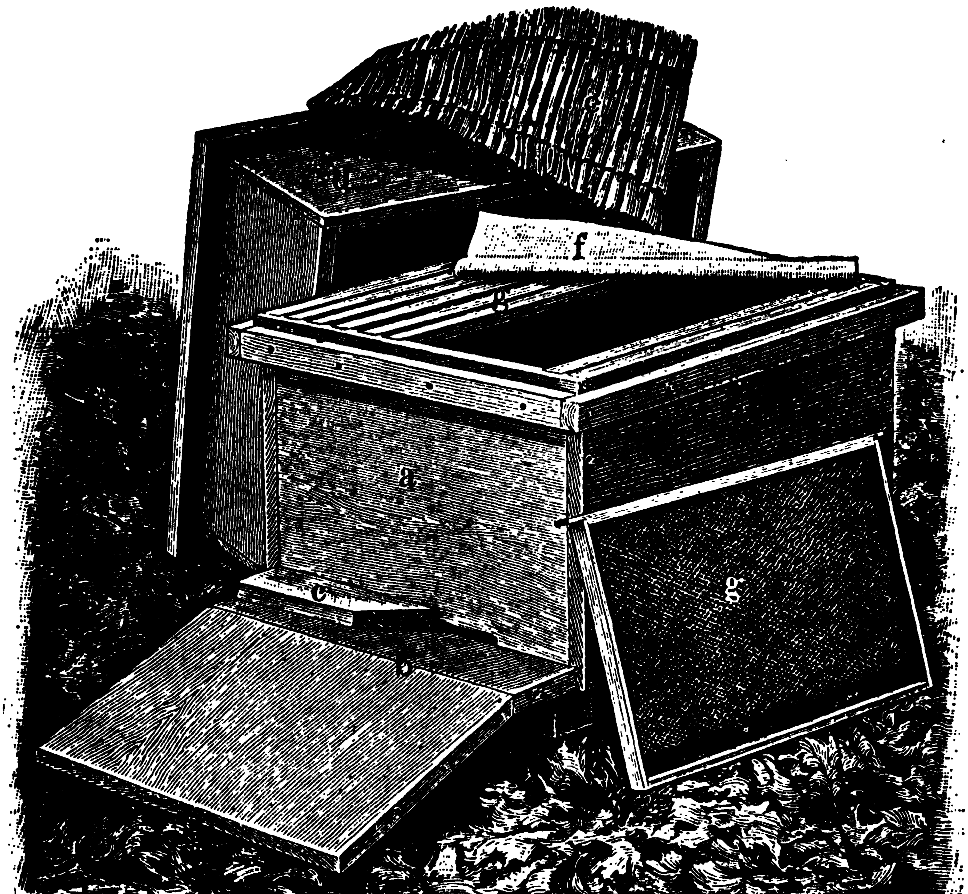



FIGURE 80. The original Dadant hive, an 11-frame hive which was adopted by the Dadants after lengthy experiments with hives of many sizes.

*The ten-frame or standard Langstroth hive* (Fig. 81) is used most universally and contains ten frames, 9⅛ by 17⅝ inches, spaced 1⅜ inches center to center.* *The eight-frame hive* is the Langstroth hive reduced to eight frames of the above dimensions and spacing. The eight-frame hive is not used extensively today.

*The Jumbo hive* contains ten frames of the Quinby depth, 11¼ inches, and the Langstroth length, 17⅝ inches, spaced 1⅜ inches from center to center. This hive sometimes is called the Quinby hive but differs from the original Quinby which had eight frames 18½ inches in length. The Jumbo hive is not used extensively today.

*The Modified Dadant hive* contains eleven frames of the Quinby depth and the Langstroth length, but the spacing is 1½ inches center to

*The ten-frame hive also is available in a double-walled hive, providing for year-round protection when wintered in one story. However, one story usually is not considered sufficient to contain a colony of ample strength with abundant stores for winter.

center (Fig. 81). This spacing, which was recommended by Quinby, facilitates removal of combs, allows more room for clustering of bees in winter, and provides for better ventilation as an aid in swarm control. The Modified Dadant hive ranks second to the ten-frame hive in its use by beekeepers; its popularity in commercial production is increasing.

The modern beehive consists of a hive stand, the bottom board, a sufficient number of bodies containing the frames and combs of the brood nest, the inner cover, and an outer cover. White pine and cypress afford good materials for the beehives although redwood, basswood and cedar sometimes are used. The parts that tend to rot quickest are the outer cover, bottom board and hive stand. If the bottom boards and hive stands are made of cypress and coated with a preservative, they will last as long as the bodies. The tops should be covered with galvanized iron sheeting and well painted, or with aluminum sheeting.

Mitchener[7] showed that two coats of good white paint applied to galvanized roof covers provides a temperature within the hive which is about 5° F. lower than when aluminum or other kinds and colors of paint are used. It is the usual practice to allow galvanized iron covers to weather for a year or two before painting so that the paint will adhere. If it is desirable to paint them when new, they should be washed with vinegar before they are painted. Connor[8] recommends red oxide

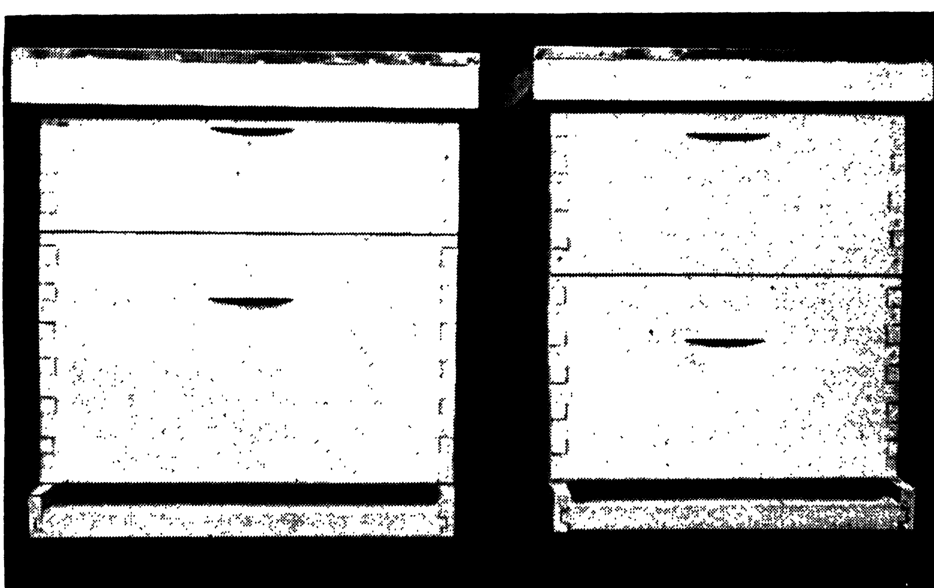


FIGURE 81. The two standard hives of America: the one and one-half story Modified Dadant hive (left) and the two-story, ten-frame Langstroth hive (right).

[7]Mitchener, A. V. 1940. The effect of color of hive covers upon the temperature within the hive. *Jour. Econ. Ent.* **33**:649-650. (Also *Amer. Bee Jour.* **81**:323-324. 1941.)

[8]Connor, John. 1941. The painting question. *Gleanings in Bee Culture* **69**: 421-422, 471.

barn paint as the best metal preservative but does not record its insulation value. All parts of the hives that are exposed to weather should be protected with paint.

Although the hive stand is not used often in commercial beekeeping practice, it is desirable because it prevents the bottom board from rotting, keeps the hive off the ground where grass and weeds obstruct the entrance, reduces dampness within the hive, and usually serves as an alighting board for incoming field bees. Hive stands made of concrete are ideal for permanent locations.

The bottom board is reversible, permitting an entrance 7/8 inches deep and the width of the hive, or a shallow entrance of 3/8 inch. It can be removed readily in order to clean it of dead bees and debris. By the use of an entrance block, the entrance can be kept small in winter or early spring, or enlarged to a full opening by its removal for crowded conditions or during warm weather.

The frames, as made by most manufacturers, are of the "Hoffman" style which touch each other along the upper third of their end bars, thus providing self-spacing. The width of the top bar usually is 1 1/16 inches, permitting more than a bee space between the frames. The underside of the top bar is cut away to make a wedge which is nailed into place to hold the foundation. The end bars contain holes through which wires may be threaded and fastened for holding the comb foundation. The bottom bar may be solid, grooved, or two-piece to provide for insertion of foundation used by the beekeeper.

The top of the hive is protected with an inner cover and an outer cover. The inner cover contains an oblong hole for receiving a bee escape and serves as an escape board when removing honey. The outer cover is usually of the type that telescopes over the top of the hive to a depth of an inch or more, and is covered with galvanized iron or aluminum sheeting. It is commonly called the "metal cover." The Excelsior cover is made entirely of wood with the top sloping slightly to each side and the ends telescoping over the front and back of the top of the hive.

In the production of extracted honey, the supers are full-depth or shallow bodies containing frames of foundation or drawn combs. The majority of beekeepers using the Langstroth hive prefer full-depth bodies for supers. However, many prefer shallow supers because they are easier to lift when filled with honey, and the queen is not so likely to go up into them for egg laying when the brood nest becomes crowded. Shallow supers for the ten-frame hive are 5 5/8 inches deep and take a 5 3/8 inch frame. Shallow supers are always used with the Modified Dadant hive and are 6 5/8 inches deep and take a 6 1/4 inch frame.

Shallow supers are used in the production of section comb honey and bulk comb honey. The standard comb honey super is one-half the depth of the ten-frame body, approximately 4 3/4 inches, and contains one tier of sections (see Chapter XII, "The Production of Comb Honey"). The

comb honey super can be turned to the production of extracted honey by using the 4½ inch frame. Any of the sizes of shallow supers described above may be used for producing bulk comb honey.

## Bee Comb Foundation

Comb foundation is a sheet of pure beeswax embossed on both sides with the bases and the beginnings of the cell walls of the comb of the honey bee. It is inserted in a frame and placed in the hive where it becomes the midrib or base of the comb which the bees complete. It is astonishing as well as pleasing to see how quickly a colony of bees will build its combs from foundation.

The cells of comb foundation are ordinarily made of worker-bee size, as a sufficient population of drones is provided by a few small areas of drone cells which the bees usually construct along the bottoms and corners of the combs. Inasmuch as the bees draw out the foundation according to the size of cell embossed on it, a large force of worker bees is obtained. In fact, when frames are furnished with full sheets of worker-size comb foundation, colonies can be induced to abandon their natural trait of building one-fourth or more drone-size cells.

The proper use of comb foundation has many advantages (see Chapter V, "The Honeycomb," and Chapter IX, "Common Practices in Management"). Straight combs are obtained which permit easy and rapid manipulation of the colonies. The removal of honey from the supers is greatly facilitated. At least half of the honey and much of the labor required by the bees in the construction of combs is saved. These advantages, plus the control of a desirable population of worker bees, makes commercial honey production possible.

A few sheets of drone-cell foundation may be used to advantage in queen-rearing yards where a large force of drones of selected stock is desired. There has been some contention that, due to the larger cells, drone comb facilitates storage, rapid evaporation of nectar, and greater ease in removal of honey from the cells when extracting. The difficulty of excluding the laying queen from large areas of drone comb, however, discourages its use. In any case, a large number of drones is a detriment to the colony because they do no work and consume large amounts of nectar and honey.

### Invention and Development of Comb Foundation

Before the general use of comb foundation, natural combs were improved by assembling pieces of combs of worker-size cells, and cutting and fitting them into frames. This was beneficial, but laborious and did not result in as good quality combs as are secured today with the use of comb foundation. If the drone comb simply was removed from a colony, the bees often replaced it with the same kind. The invention and intro-

duction of comb foundation, along with that of the movable-frame hive, marked an important step in the progress of practical beekeeping.

Johannes Mehring is usually credited with the invention of comb foundation in 1857. He used a flat press which printed the rudiments of the cells on beeswax. However, Gottlieb Kretchmer[9] preceded him, about 1843, by producing a comb base by passing tracing cloth saturated with beeswax through engraved rollers. Although the principle of manufacture employed by Kretchmer is the basis of modern equipment, Mehring's methods prevailed for years.

Comb foundation has been made in Europe on plaster casts. The Rietsche press, which makes cast sheets of beeswax on which the beginnings of the cells are molded, has also been used. Similar sheets were made in this country with the Given press which has passed into disuse because of its imperfect work.

Peter Jacob, of Switzerland, improved the Mehring press and some of his foundation was imported to America by H. Steele[10] in 1865. Cook[11] credits Frederic Weiss with the invention of a roller foundation mill, in 1873, which materially advanced the production of comb foundation, and states that it was on this machine that John Long, in 1874, manufactured comb foundation which proved to be successful. A. I. Root, to whom much of the credit is due for popularizing the invention, made a roller mill, in 1876, with the help of a skillful mechanic, A. Washburn.

A number of leading beekeepers engaged in the manufacture of comb foundation for their own use. The difficulties encountered and the time required by the several operations necessary to make a satisfactory product discouraged and ended most of their efforts. Among those who were successful were Charles and C. P. Dadant who started making their own foundation in the early 70's and were furnishing quantities to others by 1880. Thus began an industry which has proved to be of immeasurable advantage to beekeepers, for comb foundation now is used wherever bees are kept.

## The Manufacture of Comb Foundation

Only pure beeswax should be used in making comb foundation. Paraffin, ceresin, and similar waxes have been added to beeswax with disastrous results. Aside from the fact that these mixtures melt at a lower temperature than beeswax and break down in the hive, the bees readily discover the difference and show a decided preference for pure beeswax foundation. Waxes of higher melting point have been used which tend to harden the comb foundation, but the combs are apt to be excessively brittle when cold.

---

[9]Kretchmer, E. 1862. *The American Beekeepers Guide*. Chicago, Ill. Wabash Steam Printing Co. p. 39.

[10]Hubbard, J. L. 1867. Artificial comb foundation. *Amer. Bee Jour.* 2:211-212.

[11]Cook, A. J. 1878. *Manual of the Apiary*. Chicago, Ill. Newman & Son. p. 204.

The most serious objection to the adulteration of beeswax in the manufacture of comb foundation is the unknown composition of the wax derived from the resulting combs. The combs of the honey bee are the sole source of pure beeswax. Therefore, comb foundation should never be contaminated with the addition of other waxes or compounds which are inseparable, whether mineral, animal, vegetable or synthetic in origin. Chemical and physical tests can detect the impurity of these unknown mixtures, but buyers of beeswax normally pay a lower price for them, or even refuse to accept shipment, because of the expense and difficulty involved in determining their compositions.

In the manufacture of comb foundation, the beeswax is sorted into two grades. The deep-yellow and brown shades are used for making comb foundation for brood and extracting frames. These darker shades of beeswax mainly come from the rendering of frame scrapings and old combs. The light-yellow shades are used for making foundation for comb honey sections and bulk comb honey frames. The light-colored beeswax is obtained from cappings and new combs.

The beeswax is carefully refined (Fig. 82) until free of all impurities. It is then made into sheets (Fig. 83) which are run through milling rolls which emboss the sheets of wax. Brood foundation is made on a mill which makes foundation having a thick base and a deep cell wall which the bees draw into combs more readily. Comb honey foundation is made on a mill which makes the bases and walls so fragile that the foundation will not stand the weight of the bees in a full-size frame.

## Grades of Comb Foundation

The best weight of comb foundation for use in the brood nest or for extracting frames of brood depth, averages seven to eight sheets per pound in the Langstroth size, 8 by 16¾ inches. The eight-sheet weight, with vertical wires included, provides only seven sheets per pound. Sheets of comb foundation for the large-size Dadant or Quinby brood frames are made heavier, six sheets to the pound in the size 10 by 16¾ inches and, with vertical wires included, five sheets to the pound. The above weights of comb foundation are known as *medium brood.* Lighter weights known as *light brood* are seldom used. Although there are one or two more sheets in each pound, combs built on them frequently are distorted, having imperfect cells unfit for brood rearing.

Comb foundation for bulk comb and section comb honey is made very light. One pound of *bulk comb foundation,* sometimes called cut comb foundation, size 4½ by 16½ inches, contains 20 sheets and has heavier walls and bases than comb foundation for section comb honey.

Comb foundation for section comb honey must be made as light as the finest machine can make it to avoid what is called the "fishbone," a heavy central rib of wax found in honeycomb built on foundation that is too heavy. Comb foundation for section comb honey is known as *thin surplus*

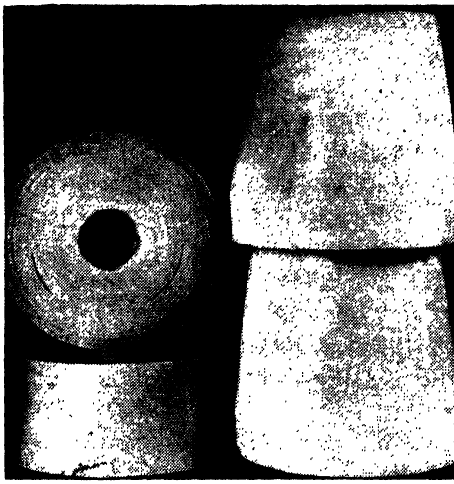


FIGURE 82. Cakes of fully refined pure beeswax and rolls of sheeted beeswax ready to be made into comb foundation.

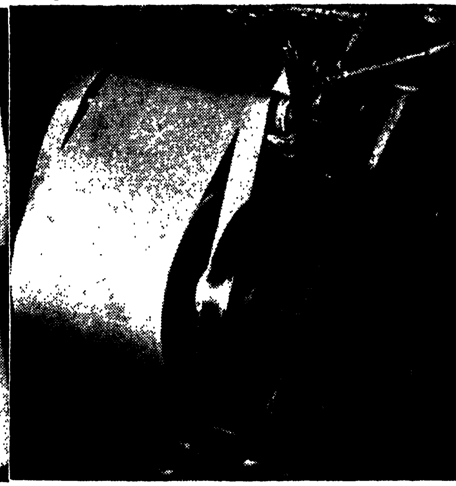


FIGURE 83. A Weed-process sheeting machine making a pliable sheet of pure beeswax and rolling it up for ease in handling.

and in size 3⅞ by 16½ inches is made 28 to 29 sheets per pound. An extra thin grade has 32 sheets per pound. Comb is not built as readily on it because the bees have to add more of their own beeswax.

## REINFORCING COMB FOUNDATION

Plain comb foundation should be reinforced in brood frames with four longitudinal, malleable tinned wires of 28 or 30 gauge. The wire is threaded through the holes in the end bars of the frame, pulled tight, and fastened. The foundation then is inserted in the frame and secured by nailing the wedge in place in the top bar. Then, with the sheet of foundation underneath, the wires are embedded by an electrical device or by a spur embedder.

Longitudinal wires are of value in holding the sheet of foundation in the central plane of the frame but are of little service in preventing sagging. To overcome sagging, Dr. C. C. Miller used light wooden vertical splints about ⅛ inch square. After soaking them in beeswax, the splints were pressed into the foundation. Although effective, they interfered with the cells and the bees gnawed them in an effort to remove them. Vertical wires offer less obstruction and nothing as good has been devised.

In 1921, Dadant & Sons perfected a method of wiring which consisted of vertical crimped wires woven into the foundation by machinery (Fig. 84). Crimped wires are better than straight ones, for the shoulders of support radiate reinforcement between the wires and prevent the beeswax from slipping downward when soft from heat. Nine or ten vertical crimped wires are ample to prevent sagging. When only seven wires are used, a little sagging sometimes is noticed between the wires.

When proper care is taken in handling and assembling the foundation and when the hives are level, the vertical wires alone may be sufficient to hold the foundation in the central plane of the frame and also to prevent sagging (Fig. 85). Generally, two to four longitudinal wires are used in addition to the vertical support to prevent the foundation from swinging in the frame. This double wiring results in as rigid and straight combs as it is possible to get (Fig. 86), and permits rapid handling and hauling long distances with little or no damage to combs, even though newly built and heavy with honey.

In 1923, the A. I. Root Company brought out a three-ply foundation in an effort to prevent the sagging of combs. This product consisted of two outer layers of pure beeswax with an inner layer, comprising 50 per

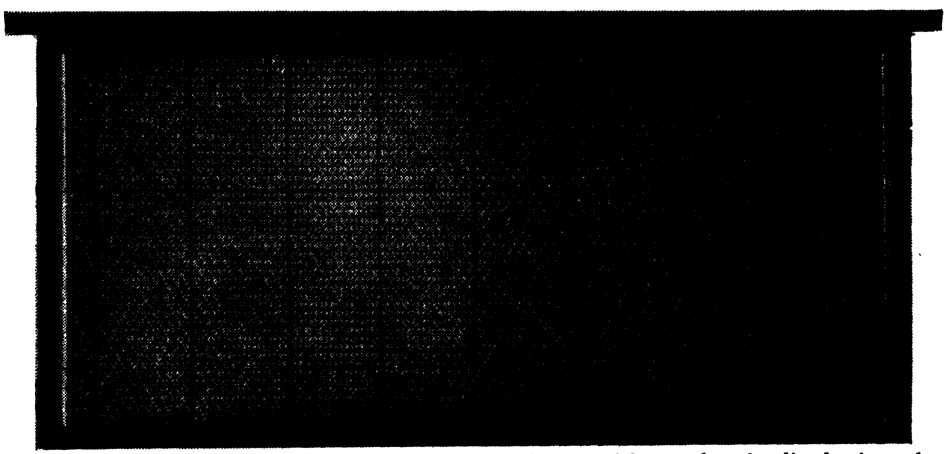


FIGURE 84. Crimp-wired comb foundation in a frame with two longitudinal wires electrically embedded—a perfect foundation for the comb.

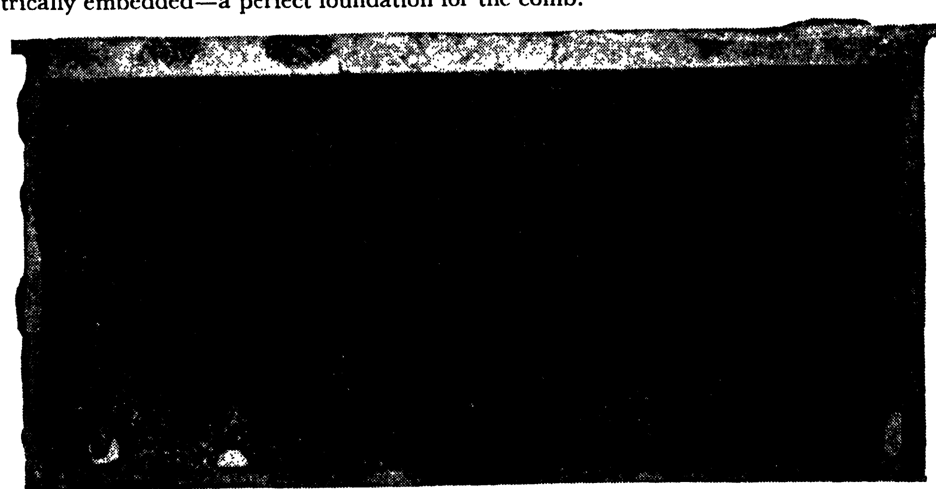


FIGURE 85. Combs constructed on foundation without vertical wiring frequently sag, resulting in distortion of many cells.

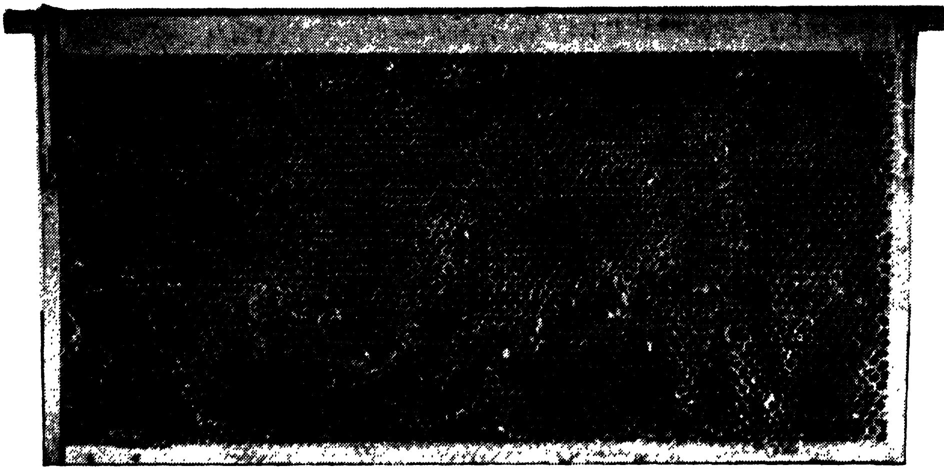


FIGURE 86. A straight comb without sag or bulge and containing nearly all worker-size cells is a great asset to beekeeping.

cent of the total finished sheet of foundation, hardened by the addition of carnauba wax. (Carnauba wax is a very hard, high melting point, vegetable wax obtained from two species of palm trees in Brazil, South America.) This product was accepted by the beekeepers, but the bees sometimes gnawed the foundation in an attempt to remove the less ductile middle ply, and it was found to be very brittle at lower temperatures. Consequently, in 1943, the Root Company patented a three-ply foundation the center ply of which contained from 30 to 50 per cent hydrogenated castor oil. The resulting sheet of foundation thus would contain from 15 to 25 per cent of added material which cannot be separated from beeswax by any ordinary means. The new product is claimed to reduce sagging of combs and breakage when handled at low temperatures, and to contain a material that is not objectionable to the bees.

Several attempts have been made to substitute other materials for beeswax in making comb foundation and even artificial combs. Metals, plastics, and other materials have not proved successful even when coated with beeswax. The bees resent foreign materials and damage combs considerably when attempting to remove them. The most ingenious invention of this kind was an aluminum comb made 1/4 inch deep on both sides of the comb base. Because it was a good conductor of heat and cold, it proved a poor incubator for the brood and was not accepted readily by the bees as long as pure beeswax foundation was available in the hive.

### CARE AND STORAGE OF COMB FOUNDATION

If properly stored, comb foundation will last for years. When cold, it becomes brittle and the least handling will crack it. If handled roughly in shipping containers when cold, the jarring of the boxes will crack the sheets of foundation imperceptibly and, although they may appear per-

fect, when handled they will fall into numerous pieces. Too much heat causes the foundation to become too soft and ductile. The bees can manipulate the beeswax best at about 90° F. This also is a good temperature for embedding wires with a spur embedder, although a few degrees lower will not be injurious.

### Position of the Cell

Separate observations by Huber and Cheshire indicate that bees usually build their combs with two sides of the hexagon vertical. Other observers, among them W. S. Pender, of Australia, found comb built most frequently with two sides of the hexagon horizontal. The cells of the comb are built both ways in about equal number, and comb also has been found with the cells built at various angles between the two. To determine whether greater comb strength was provided by a definite position of the cells, comb foundation was tried in both the vertical and horizontal positions in the Dadant apiaries. Several colonies were used in the experiment but no advantage was found for either the vertical or horizontal position.

The vertical position (Fig. 87, A), however, probably is more attractive to the eye than the horizontal one (Fig. 87, B). When the sheets of comb foundation are put into the frames the position of the cells are vertical. In cutting foundation for sections, the cells often are turned the other way and the bees accept either with equal rapidity.

## Apiary Equipment

### Bee Smokers

The bee smoker is a necessity in handling bees (Fig. 88). Smoking causes the bees to rush to cells of nectar or honey and to gorge themselves, resulting in their being less apt to sting. The smoker consists of a metal funnel for directing the puff of smoke, a metal fire pot, and a bellows for blowing air into the base of the fire pot and out of the funnel of the

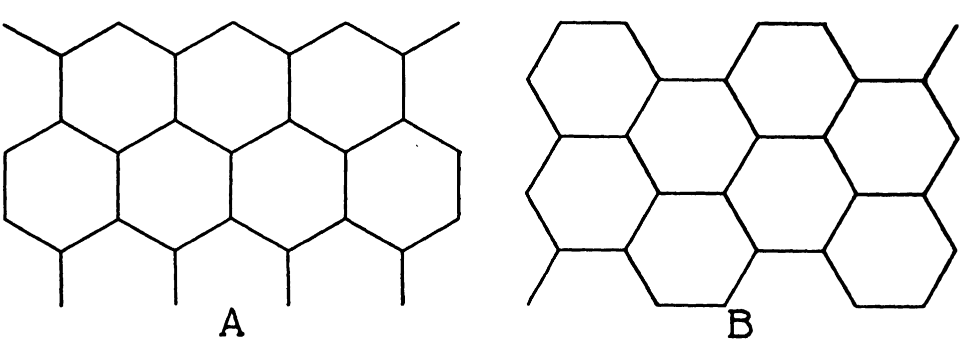



FIGURE 87. Diagram showing the vertical position of the hexagonal cells at "A" and the horizontal position at "B."

smoker. A good volume of cool smoke often is desired. Suitable fuel materials are decayed wood, coarse wood shavings, corn cobs, burlap, and corrugated paper.

### Bee Veils

The bee veil also is essential in handling bees (Fig. 89). It should either fit snugly around a hat or cover the top of the head, and should fit particularly well around the neck and shoulders. Bee veils are made either of panels of black screen wire with the top and bottom of an airy, meshed cloth material, or of meshed tulle veiling preferably having a silk-tulle face for better vision. Wire veils are preferred by many because they do not blow against the face and are more durable. However, the tulle veil is lighter and cooler, can be carried in a pocket when not in use, and can be held away from the face by a circular metal band.

### Bee Gloves

Gloves are a desirable protection for those who are not accustomed to stings. Usually, they are made with gauntlets reaching to the elbow. Few experienced beekeepers wear them because they tend to impede the handling of frames, but every wise beekeeper has a pair handy for use when working an exceptionally cross colony.

### The Hive Tool

A hive tool of some kind is necessary in keeping bees (Fig. 88). It is made of steel, having one end straight and sharpened to permit it to slip readily between supers or bodies in order to separate them. The other end, bent at a right angle and sharpened, is used for prying the frames apart. Usually, it has a V-shaped hole for pulling nails. Either end can be used for scraping combs or propolis from the hive parts, cleaning the bottom boards, and for many other purposes.

### The Bee Brush

The bee brush usually is a thin horizontal brush having light bristles about 2 inches long. It is used to brush the bees from the combs and from hive parts.

### Feeders

When there is an insufficient amount of honey in the hive for food for the bees, it is necessary to feed them honey or sugar sirup. The feeding of sugar sirup is preferred because it usually is more economical, there is no possibility of transmission of disease, and it is much less likely to incite the bees to robbing. Often the sirup is placed in a 5- or 10-pound friction-top pail having several small holes punched in the lid. The feed pail is inverted over the open hole of the inner cover above the brood nest, an empty super or hive body is placed over the inner cover and the outer

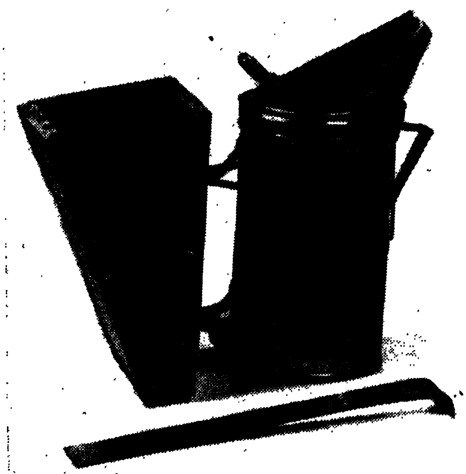


FIGURE 88. The bee smoker and the hive tool are necessary equipment when working in the apiary.

FIGURE 89. The bee veil is made in a number of ways, but the important things are vision, protection, and ventilation.

cover is placed on top. The Doolittle division-board feeder is a container the size and shape of a frame containing floats or a U-shaped piece of screen wire to enable the bees to take the sirup without drowning in it. It is placed in the hive, usually on one side, and is popular in queen-rearing yards in the South and when installing package bees or rearing nuclei. The Boardman feeder consists of a Mason jar with a perforated top and inverted over a boxlike device which is inserted into the entrance of the hive. It is not a popular feeder because the odor of feed at the entrance of hives promotes robbing. When care is taken to avoid leakage of sirup and the feeder is installed in the rear of a nucleus, it is a convenient feeder to refill without disturbing the bees.

### WIRING AND EMBEDDING DEVICES

The wiring and embedding device usually consists of a board and a spindle; the board holds the hive frame in place and the spindle supports a spool of 28 or 30 gauge frame wire. The wire is threaded through the holes in the end bars of the frame, fastened at one end, stretched tight, and secured at the other end. The sheet of foundation next is made secure in the frame by nailing the wedge in place in the top bar. The wires then are embedded in the sheet of foundation from above by means of a spur embedder or by means of an electric current which heats them, causing the wires to melt their way to the midrib of the foundation. The longitudinal wires serve to hold the comb in the central plane of the frame but are not very effective in preventing sagging of the comb.

### Bee Escapes

This device permits the bees to escape from supers of honey or from other places where they may not be wanted, such as the honey house. When used in removing supers of honey, the bee escape is fitted into the oblong hole in the center of the top of the inner cover. This combination sometimes is called an "escape board." It is placed under the supers which are to be removed; the bees can go down through the escape but cannot return to the supers. In warm weather, it should be applied the afternoon before the morning the supers are to be removed. During cool weather, more time is required for the bees to leave the supers. The bee escape is preferred by some to the acid board. The bees clean up the dripping honey in the interval before they leave the super, and there is no possibility of acid fumes injuring the flavor of honey in the combs. A special type of bee escape is available which, when installed at the top of screened openings, permits bees to escape from buildings.

### The Acid Board

This is usually made of a sheet of metal bound on the edges by a wood rim the size of the top of the hive. The underside is covered with cloth to receive the carbolic acid, and the top is painted black to absorb heat from the sun's rays. It is used to drive the bees quickly from supers of honey as the fumes of the acid are repellent to the bees. For further information, see Chapter X, "Management for Extracted Honey Production."

**Figure 89a. Bee gloves provide protection from stings on the hands and arms of the beekeeper.**

### The Queen Excluder

The queen excluder is a sheet of perforated metal, or a metal grill bound on the edges by a wood frame the size of the top of the hive, which is inserted between two bodies, or between a hive body and a super. Its use prevents the queen, but not the worker bees, from going from one body to another. Originally it was made by cutting slots in flat pieces of zinc. The newer excluders are either made of strips of wood and round wire bars spaced alternately, called "wood-and-wire," or of round wire bars having metal crossbars welded to them and contained in a wood frame, called "all-wire" excluders. The distance between the bars should be 0.163 inch permitting the passage of worker bees but not the queen or the drones. The newer excluders are preferred to the zinc because they are less destructible and because bees pass through them with greater ease.

Inasmuch as queens seldom enter comb honey supers, bulk comb honey supers, or shallow extracting supers, queen excluders are seldom used when honey is produced in shallow supers. In the production of extracted honey with full depth bodies used as supers, queen excluders are often inserted between them and the brood nest. However, it is generally thought that their use interferes with ventilation and the free passage of bees.

### Drone and Queen Traps

The Alley drone and queen trap is a grill of queen-excluder material mounted in the front of a boxlike compartment which is fitted to the entrance of the hive. It prevents the queen and drones from leaving the hive, and traps them in its upper compartment. An entrance guard is a device similar to the Alley drone and queen trap but does not contain an upper compartment. Their use in ordinary beekeeping practice is not recommended. The drones frequently clog the entrance, interfering with free passage of the worker bees and with ventilation of the hive. Confining the queen to a hive, in which the colony is in process of swarming, only delays the issuing of the swarm (see Chapter IX, "Common Practices in Management"). These devices are sometimes used in queen-rearing yards to control drone flight.

### Moving Equipment

In moving bees, it is necessary to fasten the various parts of the hive together so that the hives can be picked up and trucked to a new location. Two-inch hive staples are preferred to nails; they hold well, and are easily removed when the hives are relocated. Hive carriers of various kinds have been devised but most beekeepers prefer to pick up the hive and carry it. When moving bees in warm weather, it is advisable to close the entrance and to replace the inner and outer cover with a moving screen. The moving screen is a wood rim the size of the top of the hive,

about 2 inches in depth, and covered with screen wire. It permits the bees to cluster in this space and provides additional ventilation. In very warm weather, an entrance screen should be used at the front of the hive in addition to the top moving screen. The entrance screen extends upward from the bottom board about 8 inches and is about 2 inches in depth to provide more clustering space and ventilation. For information on moving bees, see Chapter IX, "Common Practices in Management."

### The Observation Hive

The beginner, the student, and even the experienced beekeeper will derive much pleasure from an observation hive (Fig. 90). It is made with glass sides and can be placed indoors with an entrance through a window, or can be set outdoors. Established in the spring with a comb of brood, bees and a queen, the activities of the bees and many of the intricacies of the bee colony may be watched during the season. Super space may be added if necessary. The single-frame width, two frames in depth, is preferred because the activities of the queen and the bees can be observed at all times.

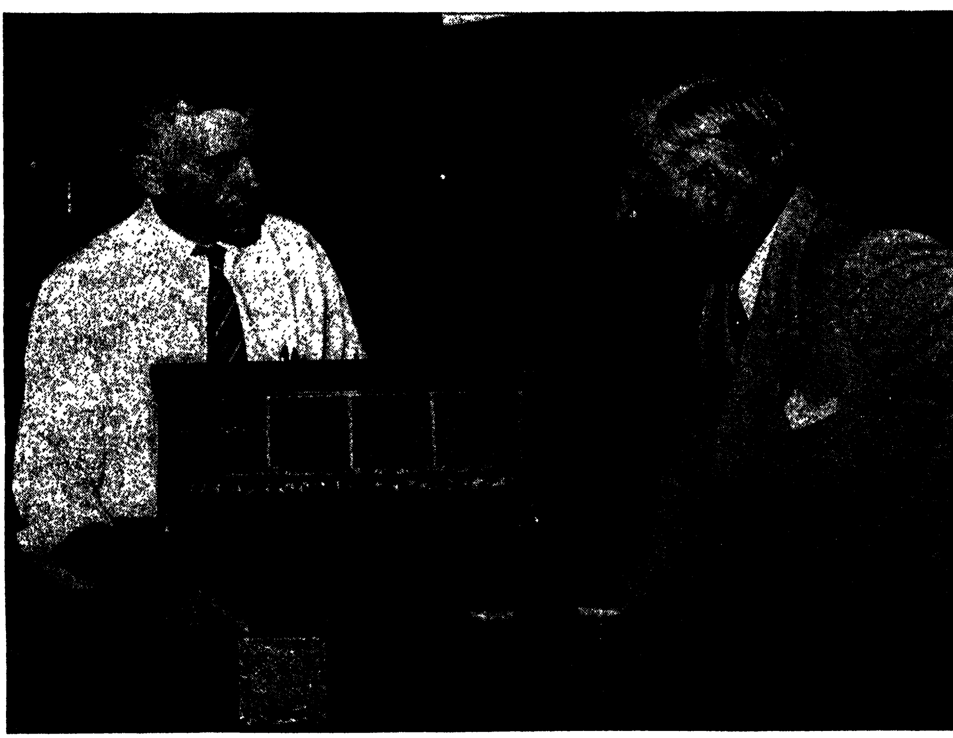


Figure 90. An observation hive at the Illinois State Fair attracts the attention of former Governor Dwight Green while State Inspector, Carl Killion, explains how comb honey is made by the bees.

# VII. *First Considerations in Keeping Bees*

BY G. H. CALE*

THE beginner in beekeeping is an enthusiast. Frequently, it is said that no matter from what walks of life new recruits are obtained, once they have tasted the experience of keeping bees, they are apt to remain beekeepers for the rest of their active lives. They may become hobbyists, side-liners, or full-time commercial honey producers, but they never get away from that fire kindled in the first joyous days of "keeping the bees." Thus, the beekeeping industry is supplied constantly with new personnel, usually well informed and able and willing to give time to the organization of the industry and to the development of new and better beekeeping methods.

The beginner soon finds that beekeeping offers him much more than financial gain. It brings contact with the out of doors—with many phases of nature. It may mean improved health for those persons whose regular work confines them indoors, diversion from ordinary affairs and routine for others, and satisfaction entirely beyond dollars and cents for all.

The beekeeper must acquire an intimate and thorough knowledge of his occupation. He must learn the habits of bees, particularly that which is of practical value to him concerning their life and colony development. He must learn what to do for them to best serve his own interests. He should be familiar with the plants in his vicinity from which the bees secure nectar and pollen. He must know when the plants bloom in order to be ready for the honeyflow. He should be patient with details and orderly in habit, for beekeeping is made up of many small duties carried out to accomplish definite objectives.

The best way to learn is to start keeping bees, acquiring the necessary experience and knowledge as one goes along. The beekeeper may seek the advice and counsel of a friendly beekeeper. Those who can spare the time are aided greatly by working a season or two with an experienced honey producer. Much help and encouragement can be obtained from

*Gladstone H. Cale. Managing editor of the *American Bee Journal*. Formerly assistant professor of economic entomology, University of Maryland. Formerly associate in the Bee Culture Laboratory, Bureau of Entomology and Plant Quarantine, U.S.D.A. Many years' experience in honey production as manager of the apiaries of Dadant & Sons and operator of his own apiaries.

correspondence courses offered by schools, or it may be possible to attend a college or university where beekeeping is taught.

It is advisable to become familiar with the literature about bees and beekeeping methods. There are many books available and many bulletins have been issued by the various states and by the Division of Bee Culture, Bureau of Entomology and Plant Quarantine, Beltsville, Maryland.

The beginner, as well as the experienced beekeeper, will find it profitable to take at least one of the bee journals. Those currently published are the *American Bee Journal,* Hamilton, Illinois; *Gleanings in Bee Culture,* Medina, Ohio; *The Beekeepers' Magazine,* Lansing, Michigan; *Modern Beekeeping,* Paducah, Kentucky; and *Southern Beekeeper,* Hapeville, Georgia. Books and periodicals also are available in many libraries, notably the Miller Memorial Library, Madison, Wisconsin, and the Everett Franklin Phillips Beekeeping Library, Ithaca, New York.

It is advisable to start beekeeping with more than one colony. Many of the operations in the care of colonies depend on the interchange of combs or the interchange of colony position (see Chapter IX, "Common Practices in Management"). Sometimes losses due to queen failure, starvation, or other reasons may be made up from the surplus bees and brood combs taken from the stronger colonies. Increase in the number of colonies often is made in the same way. At other times, it may be advisable to use the surplus bees and brood of stronger colonies to equalize those that are weaker, either to help prevent the swarming of the strong ones or to build up the field force of the weak ones, so that all colonies will secure a maximum crop of honey. Therefore, a start with five colonies is about right.

On the other hand, it is advisable not to expand beekeeping too rapidly. It is wiser to gain experience which will allow successful expansion, and to make the bees pay as they go. If the beginner lives in a city or town where there are regulations or sentiment against the keeping of bees within the corporate limits, he may arrange to place them on a nearby farm belonging to a relative or a friend, making frequent visits and attention to the bees possible. However, until the returns from beekeeping warrant the extra expense of outyard operation, it is unwise to attempt the management of bees away from home.

## Kind of Honey to Produce

Formerly, the beginner was advised to start with the production of section comb honey (Fig. 91). However, the production of section comb honey requires skill, patience, and experience which the beginner usually has not acquired. The production of bulk comb honey often is recommended for the beginner because it is easier to produce than section comb honey, requires less expensive equipment than does the production of extracted honey, and, like section comb honey, may be marketed easily.


FIGURE 91. A small display of section comb honey packaged in this manner finds a ready consumer demand.

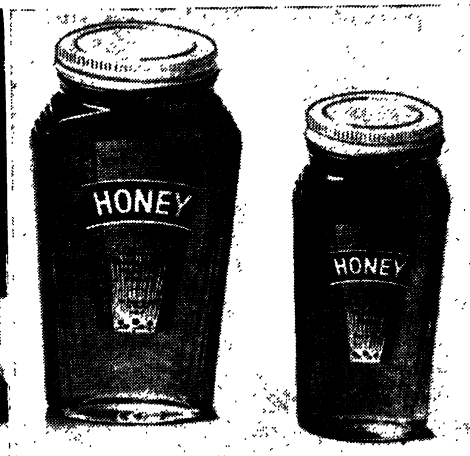



FIGURE 92. Two glass containers of crystal clear extracted honey, attractively labeled, invite the customer to buy.

For information concerning the production of these kinds of honeys, see Chapter XII, "The Production of Comb Honey," and Chapter XIII, "The Production of Bulk Comb Honey."

However, in spite of the greater investment in equipment, most beginners start with the production of extracted honey (Fig. 92). Its production does not require as skillful management as the production of either section comb honey or bulk comb honey, and the beginner is able to produce more pounds of honey with a less amount of work in caring for the bees (see Chapter X, "Management for Extracted Honey Production").

## Kind of Beehive to Use

The beginner must also decide what kind of beehive to use. Two kinds or sizes of beehives are most commonly used: the ten-frame Langstroth hive and the eleven-frame Modified Dadant hive (Fig. 93). Used much less extensively are the eight-frame Langstroth hive* and the ten-frame Jumbo hive. Because the two former types are in most common usage, the following discussion will be confined to them. For additional information on types of beehives, see Chapter VI, "Beekeeping Equipment."

The ten-frame Langstroth hive is used by more beekeepers than any other. It is reported that the depth of the ten-frame hive body was determined by the width of a board which Langstroth was able to obtain at the time he developed the original Langstroth hive. It now is commonly

*The eight-frame hive and the ten-frame hive generally are preferred for the production of section comb honey.

accepted that one ten-frame Langstroth hive body is not large enough to accommodate the brood of a good queen, so two ten-frame bodies usually are employed together in what is called the two-story, ten-frame system. Sometimes a third hive body is added for additional brood expansion or for storage of honey and pollen as a food reserve during periods when bees are no longer able to obtain nectar and pollen. In the winter period it is most important to have an abundance of stores in reserve.

Many beekeepers prefer the eleven-frame Modified Dadant hive for the production of bulk comb honey and extracted honey. The hive body is deeper than the ten-frame Langstroth body, having frames of the Quinby depth, 11¼ inches, and the Langstroth length, 17⅝ inches. The deeper body is better adapted to the habits of the bees than a single ten-frame hive body. However, it is true that many of our best queens are not fully accommodated in their egg laying by a single Modified Dadant hive body. This is overcome in the Modified Dadant system of manage-

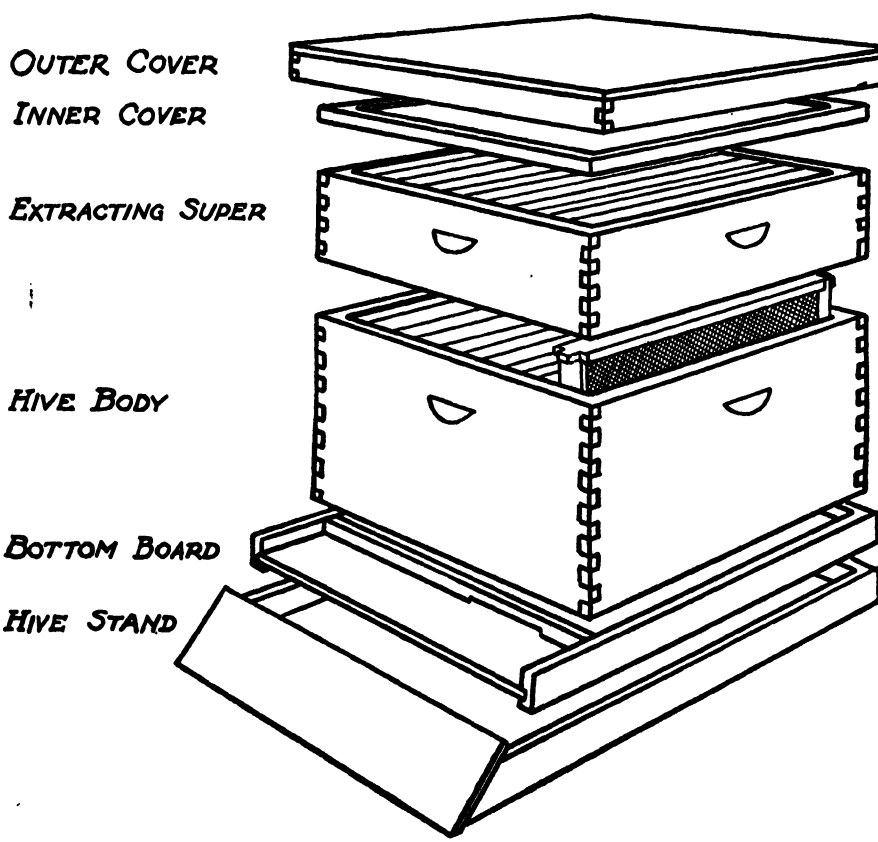



FIGURE 93. Diagram of the various parts that comprise the beehive, in the order in which they are assembled.

ment by providing the hive with a shallow super on top as a food reservoir. There is a certain amount of extra room available in the super for the egg laying of the queen, thus providing additional brood space when needed. In general, the Modified Dadant hive requires less attention than the ten-frame hive so the beekeeper is able to take care of more colonies in a given time.

In comparing the cost of equipment, let us consider the equipment required for the production of at least 100 pounds of extracted honey by one colony, an amount usually accepted by commercial beekeepers as a paying crop. With the ten-frame Langstroth hive, two bodies are usually sufficient for a brood chamber and two bodies for the storage of the surplus honey, with frames and foundation for each and a bottom board and cover for the hive. This will accommodate from 100 to as much as 140 pounds of honey depending on the fullness of the combs and the ripeness of the honey. When Modified Dadant equipment is used, a hive body and a shallow super are needed for brood and stores, and three shallow supers to contain the surplus honey, with frames and foundation for each, and a bottom board and cover. This will accommodate from 100 to as much as 130 pounds of honey. At current prices, the Modified Dadant equipment will cost about 10 per cent more than the Langstroth.

Directions for assembling hive equipment are supplied by the manufacturers, but many details of the work can be learned only by experience. Hive bodies and supers should be firmly nailed at each joint after all are fitted snugly. Frames should be assembled in such a way that the V-edges of the shoulders rest against the flat shoulders of the adjoining frames. It is advisable to buy equipment that is made accurately so that it will fit well and assemble readily and securely. Well-made equipment of good clear lumber is the best investment.

## Kinds of Bees and How to Secure Them

There are three races of bees available in this country: Italian, Caucasian, and Carniolan. The Italian bee is available from many sources; in fact, Italians are so generally available that, when the name of the race is not mentioned in an advertisement, one may assume that they are Italian bees. All things considered, the better strains of Italian bees are to be recommended to the beginner. Caucasian and Carniolan bees are available from only a few sources. For additional information concerning kinds of honey bees, see Chapter II, "Races of Bees."

Now that the mating of the honey bee may be controlled with instruments, there is an increasingly active interest in bee breeding. The adaptation of strains of bees to suit definite requirements will make it possible to secure bees for specialized uses, such as bees for comb honey production or for pollination. The adaptability of bees to climatic conditions may also produce bees more suited to definite geographical regions. Bees

with a high degree of resistance to American foulbrood already have been developed.

The purchase of package bees with queens is the procedure usually followed by the beginner in securing bees. The production of package bees is a well-established industry in the South and in California and neighboring states, offering a reliable source from which to secure new bees. Advertisements of package-bee producers can be found in the bee journals, and it is convenient for the beginner to send his inquiry to those who appeal to him. The beginner thus is able to handle as many colonies as he desires, increasing gradually from a small start (Fig. 94).

A friendly beekeeper may start the beginner with colonies already established in hives. It is best, however, to use great care and caution in buying fully established colonies, even when the seller is completely reliable. A skilled beekeeper will know whether his bees are healthy, but the fact that a colony is apparently healthy when purchased does not mean that it will remain so. There may have been disease in the colony at the time of purchase, or it may have become affected with disease later from other bees in the locality to which it is moved. For further information concerning bee diseases, see Chapter XXIII, "Diseases and Enemies of the Honey Bee."

Often beginners start by securing bees in box hives or log gums and transferring them to modern hives. This is possible, but experience is needed in transferring them in order to have colonies in good condition when the work is finished. Methods of transferring bees to modern hives are discussed in Chapter IX, "Common Practices in Management."

If it is decided that the best way to secure bees is to purchase package bees, the packages should be ordered well in advance of the time they are expected to reach the purchaser. They should arrive between April 10 and May 10, depending on the latitude or how early spring comes. They should be received early enough to allow 8 to 10 weeks for the new bees to become fully established and to build as large a field force as the season will permit by the time of the main honeyflow.

Upon arrival, the packages of bees should be placed in hives as expediently as possible. Methods of handling and installing package bees are discussed further in Chapter IX, "Common Practices in Management." It is advisable, when possible, to install package bees on fully drawn combs containing some honey and pollen. When package bees are installed on comb foundation, they should be fed sugar sirup and carefully managed until they are fully established. If properly cared for, the package colony may secure some surplus honey from summer or fall honeyflows; they should at least become full colonies before winter.

Some producers in the South furnish bees established on combs, called nuclei or comb packages. For further information concerning these types of package bees, see Chapter XXI, "The Production of Queens and Package Bees." The nuclei and comb passages cost more than the regular

FIGURE 94. This small apiary was established with package bees received in early spring, and is ready for the honeyflow with supers having been added for storage of the honey crop.

packages of bees without combs but develop into colonies more rapidly and usually give a better accounting the first season. Most states frown on shipments of bees on combs because of the possibility of disease being brought in with the bees. However, inspectors of bees in the South make every possible effort to insure freedom from disease in the apiaries of the shippers, thus minimizing the spread of disease from such sources. If the purchase of nuclei is desired, however, one should know the regulations of his State so as to be within the law in shipment.

Many beginners have started with bees by catching a swarm, while others have bought swarms which beekeepers have caught and hived in modern equipment. Early swarms that are large, if properly handled, may build to colony strength and produce a crop of surplus honey the first season. Most swarms are not cast until midsummer, or at the beginning of the summer honeyflow, and usually will do little more than become full colonies the first year.

## How to Avoid Bee Stings

If it were not for the fear of being stung, bees would be as common on farms as poultry, and many more would be kept in city back yards. Because he is not accustomed to bee stings, the beginner at first may fear their effect. The penetration of the sting is always felt, no matter how many years are spent with the bees, but the swelling, itching, and local

fever produced by stings becomes less as time goes on, until the operator actually acquires immunity. The seasoned beekeeper thinks no more of a sting on the hand or arm than a woodsman thinks of a slight scratch from a thorn.

To avoid being stung, a good bee veil, fitted or tied snugly around the collar or shoulders, should be worn. The shirt sleeves may be rolled down and a pair of gauntlet bee gloves can be worn. When you go among bees avoid wearing dark or woolen clothing; white or light-colored cotton material is best. A bicycle guard can be worn around the cuffs of the trousers to prevent bees crawling up pant legs, or the pant legs can be stuffed inside the socks. Some prefer to wear high-top boots or leather puttees. Women should wear clothing similar to that worn by men.

In attempting to sting, the bee first must take a firm hold with its claws. On feeling this, the beekeeper often is able to brush off or kill the stinging bee before the sting penetrates the skin. If the bee has managed to insert her "stinger," the sting should be removed as quickly as possible (Fig. 95). This can be done by scraping it off with a hive tool or the thumb nail. One should not attempt to pick it off with the fingers because it will result in squeezing the poison sack, causing the poison to be injected into the wound. If itching or swelling result, one should not rub the place because it will cause greater pain and swelling. Applications of cold cloths seem to be the best treatment. Since the odor of the

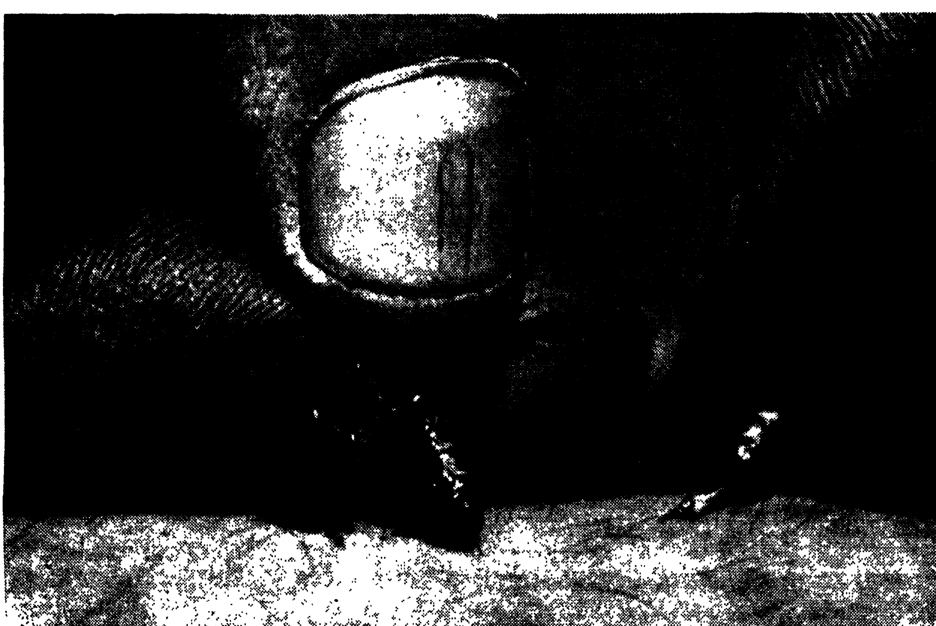


FIGURE 95. The bee at left is being induced to sting by being held against the arm. The bee at right has already inserted its stinger, and the operator is demonstrating what happens to the bee when it attempts to remove its barbed sting.

sting seems to infuriate other bees to sting, the operator should beat a retreat if stings affect him seriously. If the skin becomes blotched and the breath shortens, a doctor should be called immediately. Adrenalin, administered by a physician, is a specific antidote when bee stings cause a general systemic reaction. Ephedrin is also a remedy when the help of a doctor cannot be obtained.

The temper of the bee varies with the bee itself, weather conditions, the time of day, the time of the year, the care of the operator, and the honeyflow conditions. An exceptionally cross colony is rare among pure Italian and Caucasian bees. When colonies are cross, it is only necessary to requeen them with new queens from a more gentle strain. As soon as the population of the colony has been replaced by daughters of the new queen, the colony will have lost its temper.

The methods used in handling the bees have much to do with whether the operator is stung. This is particularly true of the judicious use of smoke. The smoke causes bees to fill themselves with honey, apparently in anticipation of the disaster which smoke suggests, but more likely due to their instinct to fill themselves with honey when disturbed by any means. Langstroth has stated clearly that: "A honey bee when heavily laden with honey never volunteers an attack, but acts solely on the defensive."

Fortunately, cases of severe stinging are not common, and with the exception of those who are hypersensitive to bee stings, no one need have fear of them if attired in suitable clothing and a veil, and if other precautions are taken.

## How to Use the Bee Smoker

To obtain smoke, many amazing materials are used for fuel. Ground or broken corn cobs, dry decaying wood, the bark of trees, paper, cloth, sumac bobs, burlap, fallen leaves, hay wisps, dry grass, oil-soaked materials—each beekeeper has a favorite fuel material. Usually, some of the fuel material is lighted and placed in the bottom of the fire pot where the air from the bellows causes it to flame before the balance of the fuel is added. Single-ply corrugated board, 4 inches wide, rolled to a diameter that will fit readily into the metal fire pot, and then soaked in a solution of saltpeter and dried, makes an ideal tinder with which to start the smoker fire. The smoker fuel then is added on top.

A cool smoke puffed gently and used only when necessary will be found most effective. Smoking when it is not necessary, or smoking excessively, actually may increase the tendency of the bees to sting. A hot smoke containing sparks causes them to act similarly, being frequently of no benefit at all.

The smoker in time will become coated inside with a black sooty or tarlike formation. In daily use, the smoker may be kept clean by scraping

the barrel of the metal fire pot and the funnel with a hive tool before lighting. Occasionally the grate of the fire pot becomes clogged making it necessary to remove it for cleaning. Should the draft pipe receiving air from the bellows become obstructed, a wire will free it of any accumulation. Properly cared for and kept dry, the smoker should last for years. Parts may be bought separately and the damaged parts replaced.

When the smoker is no longer needed, the lighted fuel should be emptied into a metal can and covered, where the fire will soon go out. One of these cans, or a piece of drainage tile covered with a stone, should be kept in every yard. Otherwise, the lighted fuel should be buried before leaving the yard. This will eliminate the possibility of a grass fire, often destructive to the colonies.

## How to Open a Hive of Bees

Before attempting to open the hive, make sure that the bee veil is properly adjusted and the bee smoker well lighted. The beekeeper will also need a good hive tool and a pair of bee gloves, although he probably will not use the gloves often. For information concerning these items, see Chapter VI, "Beekeeping Equipment."

In opening a hive of bees, do not hurry or make sudden nervous movements. Nervousness apparently contributes to secretions of the skin and bees seem to resent the resulting smell. This perhaps explains why some operators are stung more than others. The hive should be approached from the side; some beekeepers prefer to work on the right, others on the left of the colony. Do not work in front of the hive, interfering with the

FIGURE 96. A gentle puff or two of smoke at the entrance before starting to open the hive.

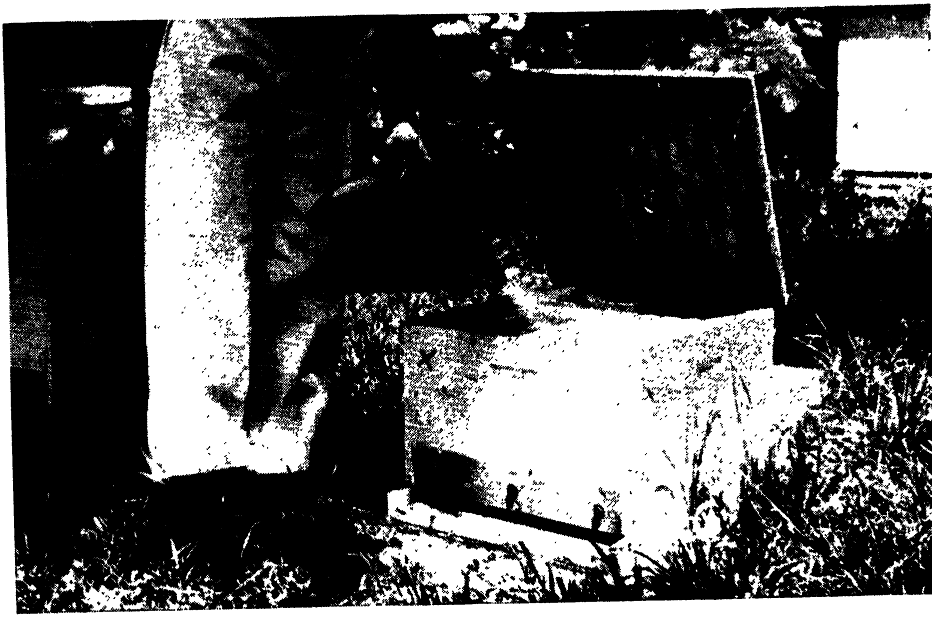


FIGURE 97. A little smoke puffed over the tops of the frames after the inner cover has been removed.

line of flight of bees to and from the entrance of the colony. A little smoke should be puffed into the entrance (Fig. 96). A large volume of smoke is not necessary and may disrupt the organization of the guards at the entrance to the extent that the colony will be exposed to the encroachment of robbers that may be lurking about.

Next, remove the outer cover of the hive and puff a little smoke along the cracks or any openings at the top of the hive. Pry up the inner cover with the straight end of the hive tool and smoke gently (Fig. 97). Some prefer to use a fabric cover, such as oil cloth, sacking, or canvas, rather than a wood inner cover. The cloth may be rolled back to any distance required for examination, and does not snap as a wood inner cover does in cool weather, disturbing the bees.

First remove the nearest outside comb, setting it on the ground at the side of the hive toward the operator. When there is danger of robbing, the comb should be covered with a cloth (see robbing in Chapter IX, "Common Practices in Management"). Sometimes the two nearest combs are removed in this manner before examination of the brood begins. The remaining combs then should be separated from each other with the hive tool, opening a sufficient space for the removal of each comb without crushing or disturbing the bees (Fig. 98). Do the work over the hive easily and quietly without apprehension. The removal of combs should be done without sudden jerky movements. The remaining combs usually are not set outside the hive, but are returned to the hive body, either to

FIGURE 98. The frame containing the comb is carefully raised without crushing the bees (left). The operator (right) has turned the frame in order to examine the brood and bees on the opposite side of the comb.

their original position or to a different position to suit whatever management requires.

A little puff of smoke is required from time to time if the bees become excited by the movements of the operator, and especially as the bees tend to fly out in an attitude suggesting they are ready to sting. Do not jar the hive carelessly and avoid striking it in any manner. If the bees become excited or cross, do not fight back by striking at them.

When examining a comb of bees, hold it over the hive and not away from the hive and over the ground. If, by chance, the queen drops from the comb being examined, she will fall into the hive or among the bees on top of the remaining combs, and not be lost or accidentally killed. Handle each comb gently and easily and few bees will drop off, and the colony will not become too excited (Fig. 98). Return the combs carefully to their place in the hive and close the hive quietly. If the work is done in the sunny part of the day, particularly on calm, clear days when the bees are busy in the fields, little difficulty will be experienced. The greatest danger in manipulating the hive and the combs is the possibility of inciting the bees to robbing.

## How Many Colonies Can One Person Keep

The number of colonies of bees that one person can care for will depend on the kind of honey he intends to produce, the condition of the equipment, the extent of his experience, the time he has available, the accessibility of his outapiaries, and whether they are located near ample sources of nectar and pollen.

In the production of extracted honey, a skillful beekeeper can care for 500 to 700 colonies of bees without employing permanent help. During the removal of honey from the colonies, extracting the honey, moving of colonies, and possibly the packing of colonies for winter, he will find it necessary to employ temporary help. When 800 to 1,000 colonies are in operation, it usually is necessary to have permanent help the year around to carry out operations successfully.

In the production of bulk comb honey, one person cannot care for as many colonies as in the production of extracted honey, due to the more exacting system of management (see Chapter XIII, "The Production of Bulk Comb Honey"). In the production of section comb honey, the system of management is even more intensive and exacting (see Chapter XII, "The Production of Comb Honey"). Generally, one person producing section comb honey can care for about half as many colonies as in the production of extracted honey, while in the production of bulk comb honey about three-fourths as many colonies can be kept.

## What Is the Cost of Producing Honey

The cost of producing honey varies considerably. Nevertheless, the average profits obtained from beekeeping compare favorably with those from other agricultural pursuits. Four chief factors largely determine the cost of producing honey: the yield of surplus honey, the cost of labor and materials, transportation costs, and the upkeep and investment in equipment.

A study of cost factors in California[1] showed an average cost for producing extracted honey of $3.93 for each colony, or an average cost for each pound of honey of 6.9 cents based on a 57-pound crop. As the yield of honey increased, the average cost of production for each colony decreased. High yields alone did not result in profits unless the yields were combined with low operating costs. In inflationary periods, the cost of operation has reached figures as high as $8 to $10 for each colony, or a cost of 10 to 15 cents for producing a pound of extracted honey.

Taking the period from 1876 through 1947, the average wholesale price for extracted honey has been 8.7 cents per pound, including the war periods. If we exclude the war years, the average price has been slightly more than 7 cents per pound. There were years when honey dropped to as low as 4 to 6 cents for extracted honey in quantities sold at wholesale; and there were years of high prices, during war periods when sugar was scarce, when the wholesale price was as much as 25 to 30 cents.

In judging the possibility of an income from the production of extracted honey, commercial producers base their figures on an average

[1]Adams, R. L. and Frank E. Todd. 1939. Cost of producing extracted honey in California. *U.S.D.A. Tech. Bull.* 656.

crop of 100 pounds to the colony each year. When average crop figures for a period of 5 or 10 years are available, it is easily possible to judge the potentials of any location.

In general, based on an average operating cost ranging from $4 to $8 for each colony, the financial returns will depend on current markets and the size of the crop. With the average, long-range wholesale price with a low operating cost and a crop of 100 pounds or more for each colony, good returns may be expected.

## Laws Relating to Beekeeping

There are laws or regulations affecting beekeeping in most states, the chief purpose of which is to prevent the spread of serious bee diseases (see Chapter XXIII, "Diseases and Enemies of the Honey Bee"). The beekeeper should become familiar with those that are in force in his State, or in any state into which he may wish to move his bees.

Some states will not allow bees on combs to come in from any other state, and combs that have been in use are not permitted if they come from outside. To undertake beekeeping then requires that new or sterilized hives and hive parts be used equipped with frames and comb foundation. Other states require certificates of recent inspection, issued by an accredited state inspector, to be submitted and a permit of entry issued before the beekeeper may enter with bees on combs.

Municipalities often issue regulations against the keeping of bees within the corporate limits because of complaints from neighbors that the bees are a nuisance. Often such regulations have been successfully contested because they did not apply to other animals in the same area that also were a nuisance. The best way out of such possible difficulty is to locate the bees so that in flying to and from the apiary they will not be likely to sting people or animals; and to establish confidence among neighbors whose objections usually are based on fear. The gift of a reasonable amount of honey to those around you will silence most of the protests.

A swarm of bees is considered as being wild in nature and becomes the property of whoever captures and hives it. Once in the air, the bees cease to be the property of the one from whose apiary they originate, unless the owner can keep them in sight with the intent of hiving them. Bees in a tree or building, once fully established as a colony, are the property of the man who owns the tree or the building. When bees are located so as to constitute a public menace and the beekeeper, through negligence, does not alleviate the situation, he is liable to prosecution.

# VIII. *The Apiary*

BY M. G. DADANT*

THE first consideration in choosing the location of an apiary is whether or not there are sufficient sources of nectar and pollen near. Bear in mind that honey bees can gather nectar and honey profitably within a radius of 1 or 2 miles, depending on the ruggedness of the country and to some extent on the prevailing winds. Even in the heart of large cities there are often sufficient sources of nectar and pollen to provide for a limited number of colonies, and even to produce surplus honey. A city lawn, a back yard, a flat roof, a pasture on a farm, a grove of trees—all will be satisfactory locations as the occasion demands. For convenience in working the bees the apiary site should be as level as possible.

FIGURE 99. A fence of this kind makes an excellent windbreak; the hedge trees behind the fence furnish additional protection.

*Maurice G. Dadant. Business manager of the *American Bee Journal*. Author of *Out-apiaries* and many articles on beekeeping. Manufacturer of beekeepers' supplies.

FIGURE 100. Trees furnish shade for the colonies and aid the bees in locating the position of their own hives. A clearing in a woods, such as this, makes an excellent apiary site.

In all instances, the neighbors' rights should be considered. The beehives should be placed so that the line of flight is away from roads, sidewalks, or line fences where the bees might interfere with the neighbor or his stock. When this is not possible, the line of flight to and from the hives may be deflected upward out of possible difficulties by obstructions such as shrubbery, trees, or even chicken-wire netting.

For winter protection, windbreaks in the form of fences, shrubs, woods, or natural slopes are desirable (Fig. 99). While the bottom of a hollow with a north slope for wind protection in winter might seem ideal, there likely would not be sufficient air drainage to prevent excessive humidity. A preferred location is a slope having a south exposure and providing good drainage of water and movement of air. The beehives should be placed with their backs to the north as protection against the prevailing winter winds, and with their entrances to the south permitting the maximum amount of sunshine on the front of the hive.

Clean, fresh running water should be available in the apiary or near by to prevent the bees from visiting the neighbors' watering troughs, fish ponds, and bird baths, and to preclude their visiting undesirable, contaminated moisture sources, particularly during drought periods. Because stagnant watering places are believed to be a contributing factor in the spread of certain adult bee diseases, it is not advisable to locate colonies where drainage is poor.

Shade is desirable (Fig. 100), but too much shade will hinder early and late daily flights. Trees and shrubs may be so dense that they prevent

easy passage of the bees to and from the hive. They also may restrict ventilation in summer. Thus apiaries located in groves or woods should be placed in clearings. This will not only give the desired sunshine, but will direct the flight of the bees upward where they will not interfere with passers-by or with livestock. Shade boards placed on top of the hives may serve as a substitute for tree shade. Trellises and arbors provide good shade but conditions restricting flight and ventilation should be avoided. In the arid regions of the Southwest, shade often is provided by a "ramada," a long covered arbor under which the hives are placed in rows (Fig. 101). In general, an airy, partly sunny, partly shaded location is preferred.

Apiary sites along rivers and streams should be on elevated ground to eliminate the possibility of floods. Grass and weeds in the apiary should be cut to minimize possibility of fire and to aid in ventilation of the colony. Grass in front of the entrances may be kept down by use of cinders, old roofing paper, boards, or similar materials, thus giving the bees an unobstructed entrance for flight and for ventilation. The use of chemical weed killers, principally 2,4-D (see Chapter XXII, "Injury to Bees by Poisoning"), will destroy most weeds found in the apiary.

In some sections of the South, Argentine ants are most annoying and destructive. They attack all kinds of food and are particularly fond of sweets and meats. In sections where they occur it is necessary to keep the beehives off the ground on platforms with legs which rest in cans of oil. Except in the very North, termites occur throughout the United States, and are particularly numerous in the South. They burrow in and consume as food the wood of bottom boards and other hive parts. Some

FIGURE 101. A "ramada" in the far Southwest provides shade for the colonies, as well as for the beekeeper. (*Photo by J. E. Eckert*)

FIGURE 102. Colonies in the South are kept on platforms as a protection against floods and ants.

of the common ants are such pests that at times they constitute a major problem, affecting apiary locations and honey houses, as well as individual colonies. For additional information concerning these insects and their control, the reader is advised to refer to Chapter XXIII, "Diseases and Enemies of the Honey Bee."

## Arrangement of Colonies

The arrangement of colonies in the apiary depends largely on the kind and amount of space available. The hives should be placed far enough apart to allow freedom for working between them. They should be set as level as possible from side to side but should incline slightly forward to permit moisture to run out of the entrance, and to enable the bees to remove dead bees and other objectionable matter more easily. Each colony may be numbered to make record keeping and management more efficient. To protect from losses due to theft, some beekeepers mark hives and hive parts so they can be identified, often by branding with a hot iron.

Colonies may be arranged in groups of two, three, four, or more in a manner which permits working each colony and allows winter pack-

ing of the group as a unit. However, the hives usually are arranged in rows. The rows should be far enough apart so that a workman in one row will not interfere to any extent with the flight of the bees from the next row back. Placing the hives 6 to 8 feet apart in rows 10 to 12 feet apart helps to prevent drifting, allows the use of a truck between rows, and eliminates the necessity of fencing the apiary for protection against cattle and sheep. In large apiaries, the rows of hives should not be arranged too uniformly in order to assist the returning bees in finding their way back to their home colonies. Occasional shrubbery or trees scattered through the yard are beneficial in this respect.

Painting of hives not only preserves them, but also helps in minimizing confusion resulting in drifting if different colors are used for alternating hives. Light colors are less absorbent of the heat from the sun's rays and thus desirable in exposed locations in summer. For additional information concerning painting of hives, see Chapter IX, "Common Practices in Management."

To combine protection, shade, and windbreak, some beekeepers have resorted to placing their hives in open sheds. However, where sufficient

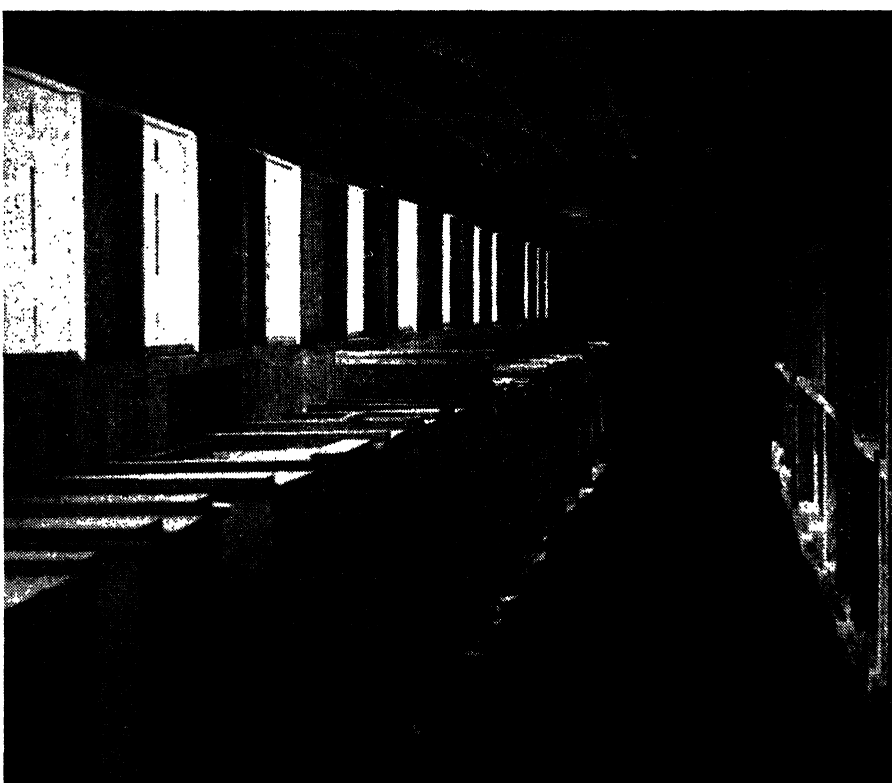


FIGURE 103. The Strittmater bee house in this country.

room is available, sheds should not be used because they confuse the bees, the hives are too close for the operator to work with comfort, and the colonies lack sufficient ventilation, becoming uncomfortably hot in excessively warm weather.

In Europe, many apiaries are placed permanently in houses. The colonies are arranged in rows along the wall, as many as two or three tiers high, with all entrances to the outside (Fig. 103). While the bees are well protected and the beekeeper is able to work them in most weather, house apiaries are seldom used by American beekeepers because the investment is large and suitable apiary locations, ample in size, are usually available.

Should the maintenance of uniform temperatures, now being accomplished by electric heating of beehives, become as popular as with poultry and other farm management, it might be possible that the house apiary will come into favor. However, until such time and for as long as conservation of space is no more necessary than it is today, house apiaries are a doubtful investment.

## Outapiaries

A wise and careful approach to the keeping of bees on an increased basis is always recommended, whether in the case of the beginner, the expanding side-liner, or the commercial beekeeper. Most beekeepers begin in a small way, starting modestly and learning beekeeping as they go. Thus they are better able to meet the problems of outapiary management when the desire for such expansion comes.

Much the same factors determine the success of the outapiary location as those which affect the home apiary. However, due to the additional expense of trips that will have to be made in the management of bees, greater care must be exercised in selecting a site which will afford a maximum honey crop. Also more important are minor sources of pollen and nectar for proper build-up of the colonies before the main honeyflow and for maintaining them after the honeyflow.

Thus, before one finally decides on an outapiary site a study of the rainfall, temperature, soils, natural flora, cultivated crops, and crop rotation practices becomes of prime importance. A variation in location may mean the difference between a 50-pound and a 150-pound crop and similarly between obtaining a fine white honey or a darker grade. Especially if outapiaries are to be established permanently a very thorough study of all pertinent factors should be made.

While inspection measures and disease laws are tending to bring bee diseases under control, the advantages of locating in a disease-free territory are to be seriously considered. The beekeeper should learn as accurately as possible from neighboring beekeepers and from apiary inspection sources the prevalence of bee diseases in the territory under con-

sideration. The cost of disease eradication can be an appreciable item of expense aside from the loss of crops from those colonies which may have to be destroyed. In the interest of disease control, regulations in many states forbid bees on combs to enter from outside, while other states require a certificate of recent inspection before bees on combs may be admitted, or before bees may be moved from one part of the state to another location. Before attempting to move bees to a new location, one should become acquainted with the regulations which apply. A letter to the state apiary inspector, or to the inspection department of the state to which one wishes to move, will bring the desired information.

In choosing apiary sites, consideration should be given to overstocking. No matter how fine the location, there is always the possibility of placing more bees in a territory than it can support profitably. While there is no specific law against moving bees into a section already amply stocked, common sense and courtesy suggest strongly that no beekeeper do this. Some of the irrigated sections have become so overpopulated

FIG. 103a. A famous experimental apiary and the laboratory and home of the late Dr. Lloyd R. Watson of Alfred, New York. It was here that artificial insemination of queens was developed and perfected.

with bees that the honey crops doubtless have been reduced. In one instance, at least, a state regulation has resulted requiring a beekeeper to obtain a permit before occupying a territory with a given number of colonies. Agreements with other beekeepers for apportionment of available locations is desirable. Co-operation with other beekeepers will always pay big dividends.

If the beekeeper is just expanding to the extent that his home yard is insufficient for his colonies, his problem is somewhat different from that of the established beekeeper who is seeking a location for another of his outyards. In the former case, it is likely that he will want his first outapiary location close to his home yard to keep at a minimum the cost of transportation to and from the outapiary. Thus he may be content with a smaller crop, although a paying one, in order to fit the operations of his outyard into that of his home apiary.

The established beekeeper will select locations which fit best into a plan of operation from one or more central points and give the largest possible crops of good quality honey, produced at the lowest cost. Other than selecting a suitable place to live, he may sacrifice all else to honey production. In some cases it is necessary to make an intensive study of a large section of a state to determine the best locations. With good roads and truck transportation one need not restrict operations to a small territory. Especially in heavy-yielding sections where the cost of production will permit additional travel, apiaries may be as much as 50 miles from the central operating point. However, most apiarists restrict their apiary system to a radius of 20 or 30 miles.

If at all possible, the apiary should be accessible over good roads, thus making it possible to reach it under all weather conditions. In spring it is often necessary to get to the bees for feeding or for supplying supers. It is exasperating and costly when muddy, impassable roads necessitate the carrying of feed and equipment by hand. One such experience usually suffices to prevent a recurrence.

Apiaries, particularly permanent ones, should be located on the property of congenial and friendly people who understand the advantages of having bees on their farms to pollinate legumes, garden crops, fruits, and berries. Usually a farm owner is to be preferred to a renter because the former is more permanently located. Where possible, the apiary should be located near the farm home so that the farmer can watch out for the bees, such as protecting from theft and replacing covers blown off by storms. While beekeeping practices tend to prevent swarming, the nearby farmer may be willing to catch swarms and hive them during the beekeeper's absence.

When livestock is present, the outapiary usually should be fenced. A low woven-wire fence will suffice for hogs and sheep, but a higher fence, consisting of several strands of barbed wire or one or more strands in addition to a low woven-wire fence, is required for cattle and horses.

In the mountains of the West, the cutover timber country of the North, and near the swamps of the Southeast coast, bears are often destructive in robbing hives. Formerly, it was necessary to erect stockades around apiaries in these places, in addition to hunting and trapping the bears.[1] However, in most cases, the electric fence has proved more effective and economical. At least four strands of barbed wire are recommended with the first and third strands from the top connected to the controller and a six-volt, hot-shot battery, and with the second and fourth strands attached to the ground wire. Some prefer six strands with every other strand connected to the controller and battery. In dry locations, some charge all the wires, placing a strip of chicken-wire netting at the base of the fence to be sure that the bear makes a good contact with the ground to complete the circuit.

The charged wires should be insulated at the posts and care taken that limbs of trees, shrubs, and weeds do not touch them, causing short circuiting, particularly in wet weather. The battery should be a dry-cell, weather-proof, six-volt unit which should serve continuously for three months. However, a wet storage battery having a rating of 90 ampere hours or higher is satisfactory and will last about the same length of time. Due to the possible danger to people, the fence should be marked conspicuously with signs at frequent intervals to warn passers-by that the wires are charged.

A universal question concerns the number of colonies to be kept in an apiary. This can only be determined by the abundance of floral sources of nectar and pollen. In the eucalyptus regions of Australia, 200 or more colonies may be kept in one location without serious reduction in the average colony production. Years ago, when E. W. Alexander was keeping bees in the buckwheat region around Delanson, N. Y., he had as many as 700 colonies in his home yard. The same location today probably would not support more than 10 per cent of that number, due to a reduction in the buckwheat acreage. In good seasons, sweet clover sections of the Midwest may provide maximum colony production for as many as 200 colonies. In northern Georgia, as in many areas where only a moderate amount of flora is found, the number of colonies in an apiary should not exceed 50.

Permanent apiaries should contain the maximum number of colonies which the territory will support in poor years. As mentioned previously, minor sources of nectar and pollen play an important part in the total honey crop. It is desirable to regulate the number of colonies in the permanent apiary to the number which can be built to peak strength on the minor floral sources previous to the main honeyflow. For the average location, about 50 colonies are usual, with the number varying either way

---

[1]White, Lewis. 1947. Don't try to fence bear—trap them. *Gleanings in Bee Culture* 75 (11):652–653.

depending on the amount which can produce a maximum crop of honey at a minimum expense of operation.

Nectar and pollen availability and the contour of the country likewise determine how close apiaries may be placed to each other. With a profuse supply of nectar in hilly country, apiaries may be placed 2 to 3 miles apart; in open country, perhaps 3 to 5 miles would be better.

## Apiary Rentals and Contracts

Farmers are friendly and co-operative folks. Certainly this has been evident to beekeepers. Nevertheless, it is always advisable that there be a definite and written contract covering rentals, locations, and related matters. In spite of this, nothing more than a verbal agreement is made with the farmer in 95 per cent of the cases. The rental charge varies: some beekeepers settle with the farmer with a can or two of honey; some pay 5, 10, or even 25 cents for each colony; and others pay $5, $10, or even $25 for each location.

More and more, farmers are coming to realize that they must depend upon the honey bee for the best pollination in order to obtain maximum fruit and seed yields. As a consequence, honey bees are being sought and growers are even paying beekeepers to place bees on their properties, regardless of the possibilities of the locations for honey production.

## Working Bees on Shares

Occasionally the apiarist finds it necessary to rent all or part of his bees on a share basis to another beekeeper, or he may wish to add to his income by keeping bees for another owner on a share basis. It is good business practice for the agreement to be detailed and in writing so that misunderstandings may not occur when the final settlement is made. Usually, the owner furnishes the bees, hives, supers, honey house, extracting equipment, and the containers for his share of the crop. The share worker furnishes the truck, all of the labor, and the containers for his share of the crop. On such a basis, the honey and beeswax crop usually is divided half to the owner and half to the share worker. The circumstances affecting each agreement naturally will be somewhat different in each case, particularly with regard to who should pay apiary rentals, who should pay for necessary feed, how swarms or increase should be apportioned, and many other matters. Consequently, a written agreement always should be made between the two parties, even though it is necessary for a lawyer to prepare it.

# IX. *Common Practices in Management*

BY G. H. CALE*

SUCCESS in beekeeping depends upon a proper exercise of the knowledge of colony organization, growth, and behavior in relation to environment as affected by seasonal changes and the occurrence of nectar- and pollen-bearing flora. In beekeeping it is not possible to use fixed rules or exact routines. No two seasons are ever alike and the beekeeper who has the truest understanding of the habits and activities of bees and of the fundamental reaction of the colony to its environment is the one who is most likely to succeed.

In the intelligent management of a colony of bees there are practices which do not come in any natural succession throughout the season, but may be necessary to employ when conditions require their use. Each of these practices is important and vital to the well-being of the colony and to the production of a maximum crop. In this chapter they are presented separately so that in the next chapter, "Management for Extracted Honey Production," it will not be necessary to explain at length the common practices which are required from time to time but are not definitely related to seasonal sequence.

With a thought to their probable use, the discussion of these common practices is given in the following order: How to prevent robbing, how to feed bees, providing water for bees, the management of package bees, queen management, how to prevent and control swarming, how to move bees, the prevention of drifting, how to unite bees, how to transfer bees, supplying ventilation, securing good combs, care of equipment, keeping records, and natural factors that influence management.

## How to Prevent Robbing

Colonies of bees have little respect for each other when it comes to the possession of honey. Nature teaches honey bees to search for food and any that they can find by fair means or foul they consider their own property. As soon as bees begin to fly in the spring, their quest for food starts. They not only seek honey stores but often will turn their attention to sirups, sugar, fruit juices, and any other similar sweet material that is within easy access. They will try to rob another colony whenever there

*Gladstone H. Cale. Managing editor of the *American Bee Journal*. Manager of the apiaries of Dadant & Sons and operator of his own apiaries.

is a chance, particularly when there is little nectar in the field. Often strong colonies with the largest stores are the most apt to prey upon the possessions of weak colonies.

When supers of extracting combs still sticky with honey are given to colonies at the beginning or toward the end of the honeyflow, it is likely to cause robbing. Therefore, it is best to arrange to have such supers dried of all honey each year before they are stored, so that the excitement which occurs when wet supers are returned to the colonies may be avoided. For information concerning the care and storage of empty supers, see Chapter XI, "Extracting the Honey Crop," and Chapter XXIII, "Diseases and Enemies of the Honey Bee." Only when there is a good honeyflow and the field bees are gathering nectar freely do they disregard exposed honey. Even then, at certain times of the day or when conditions change, robbing may be resumed.

Sometimes it is difficult to distinguish between the physical appearance of robber bees and others, although robbers eventually become smooth, shiny, and almost black. They have an air of roguery and a nervous and guilty agitation. They do not alight boldly at the entrance of another colony, nor do they face the guards without fear. They seem to try to glide by the sentinels without touching them. When robbers are caught by the guards, they try to pull away. If these marauders attack a strong colony, they have difficulty in escaping with their lives. On the other hand, a bee that loses its way and alights in front of a strange hive behaves differently, shrinking to a corner, bewildered and submitting to any treatment her captors may exact.

The beginner may mistake the play flights of young bees for robbing. Young bees circle around to mark the location of the hive but there is no fighting or disturbance. These play flights occur in the middle of the day, especially on warm sunny days in the brood-rearing period. Frequently an apparent case of robbing proves to be bees coming out of the entrance and flying around their own hive to clean up honey or sirup which may be leaking through cracks. This soon is accomplished and the disturbance ends.

Some robbing is carried on so secretly that it escapes notice. The bees do not enter the hives in large numbers and no fighting is seen. Yet strange bees actually are entering the hives and carrying off the honey constantly. They sneak in at corners and cracks, pass the guards one at a time, and are observed by the beekeeper only on close scrutiny. This kind of robbing, called *progressive robbing,* is difficult to control and usually no attempt is made to do so.

Robbing, however, is seldom a menace to the careful beekeeper. He will do everything in his power to prevent it, particularly in times of dearth. If it becomes essential to manipulate colonies when robbing is dangerous, he will proceed with caution, opening the hives carefully, doing work speedily, and never leaving combs of honey exposed. He

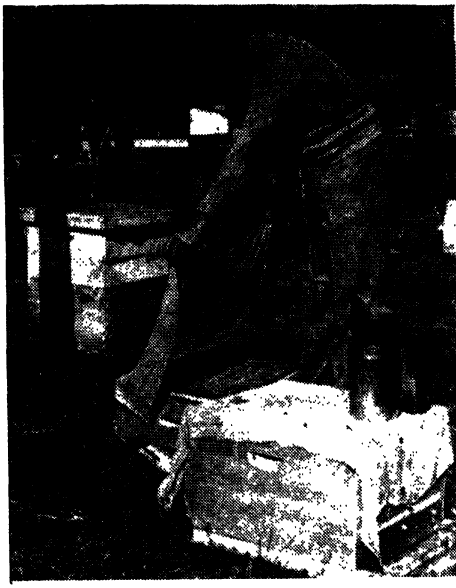


FIGURE 104. A robber cloth is used to cover a super of combs that has been set apart from the hive, also covered with a cloth.

FIGURE 105. Two robber cloths are used to cover the top of the hive, and are spread apart in this manner to remove a comb.

will cover the tops of the combs in the hive with a cloth moistened with water, sometimes containing a small amount of carbolic acid (Fig. 104). Similar cloths may be used to cover combs or bodies of combs which need to be removed from the hive when working the bees (Fig. 105).

When robbing is prevalent, the entrances of colonies should be reduced and cracks or openings in the equipment through which robbers might gain entrance should be closed. In addition to reducing the entrance, it sometimes helps the colony if a broad board is laid across from one side of the bottom board to the other. This forms a sort of porch or tunnel through which the robber must pass and in which the hive bees congregate and defend themselves. In serious cases of robbing, the porch or tunnel may be further protected by piling green grass over it. Repellents, such as kerosene, gasoline, and carbolic acid, used about the cracks and the entrance will help discourage robbers to some extent.

Another way of working colonies when robbing is quite dangerous is to use a screen wire cage, light enough to be carried by two men. This is placed over the colony to be worked. The cage may be supplied with a door so that the operator can go in and out as he needs, and a flight entrance which fits up closely to the hive is provided at a bottom corner. The top of the cage is removable so that any accumulation of bees may be let out from time to time.

Poorly established or weak colonies should be kept in an apiary by themselves. Entrances should be kept reduced and these colonies worked with extreme care as a precaution against robbing. If colonies must be

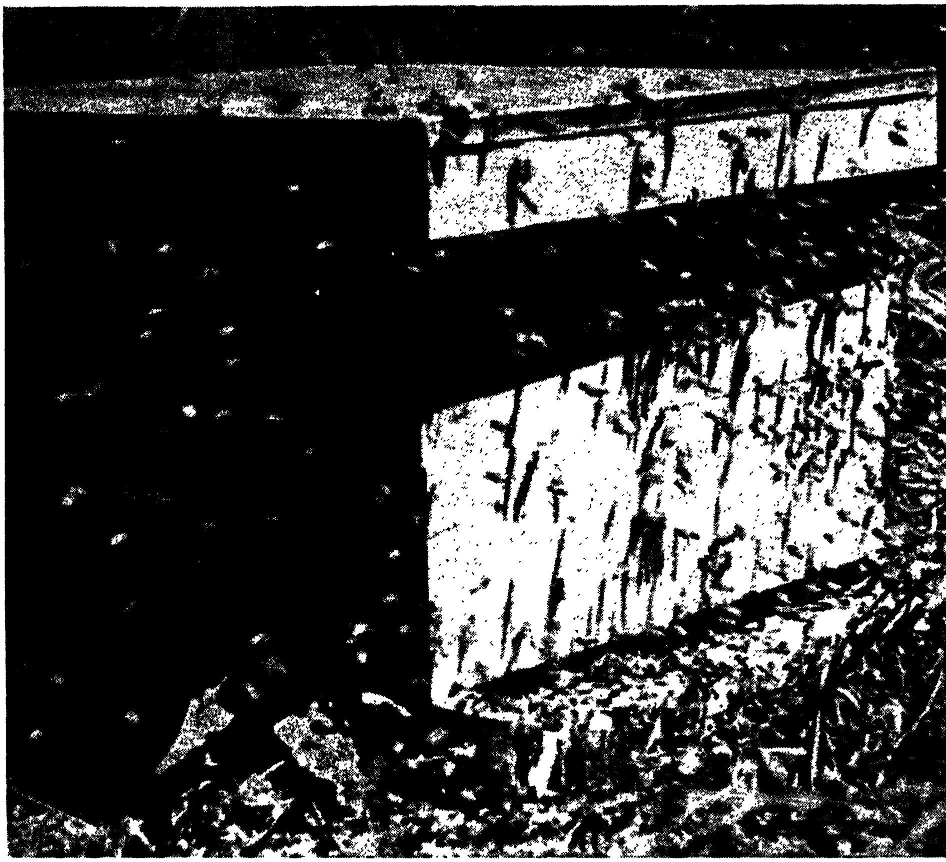


FIGURE 106. This colony is being robbed. Notice the many bees trying to get into the hive at all cracks and openings, in addition to those at the entrance.

fed, the feed may be given when the weather is inclement, in the evening, or in the early morning, and then the feed should always be placed inside the hive, never outdoors.

Nickel Jacob, whose book was published in 1568,[1] used the flour method to identify the hive from which robbers came. This consists in sprinkling the robber bees with flour in order to trace them to the hive to which they return with their plunder. Having identified the robbing colony, it is then possible to apply control measures which will effectively ease the situation.

When bees are flying vagrantly about hunting at all corners and cracks of hives, the experienced beekeeper knows that the colonies should not be opened unless it is absolutely necessary (Fig. 106). When robbing gets out of control, the bees are apt to sting fiercely without apparent reason, especially when they have exhausted the supplies they have been

[1]Fraser, H. M. 1947. Nickel Jacob. *Proceedings, Annual Report and Accounts for the Year 1946. Central Association of the British Bee-Keepers' Association.* pp. 23–30.

plundering. Even a hardened beekeeper will shrink from the punishment that awaits him until robbing is reduced.

When robbing occurs among a few colonies in the same yard as a natural consequence and not from any disturbance caused by the beekeeper, it is usually best to allow it to continue without making any attempt to stop it. It is seldom disastrous and the bees discontinue it voluntarily. On the other hand, when robbing occurs between two apiaries some distance apart, it may result in the loss of many colonies that are being robbed, and all the colonies in the robbing apiary will participate in the destruction of those colonies.

## How to Feed Bees

It is necessary to feed colonies in the fall that do not have enough stores to carry them through the winter and into spring. It also is necessary to feed some colonies in the spring even though an abundance of honey was left with them in the fall. When new colonies are being installed, such as package bees, nuclei, or divisions, feeding usually is necessary.

Except during the winter period when a large amount of stores is required, a colony should have at least 15 to 20 pounds of reserve stores at all times. When a colony is short of food, there will be little honey in the combs and the hive will be light in weight. In any period of shortage, it is a safe rule to be sure that there is some sealed honey in the combs. When there is no sealed honey, the bees may be approaching starvation.

When hives are full of bees with an immense amount of brood to feed, the stores must be watched closely. Bees are most apt to starve in the period of brood rearing before the beginning of the main honeyflow. Even in a period of honeyflow, when nectar is unavailable for any duration because of weather, the bees may require feeding. There also may be intervals in summer between honeyflows when colonies need feed to support them. If stores are reaching the point of exhaustion, bees will carry larvae and pupae out of the hive entrance. They also will drive the drones from the hive where they die from exposure.

The best feed for a colony of bees is a super full of honey; George S. Demuth called this the "automatic feeder." Beekeepers often select supers of honey for winter stores in which the side combs are relatively empty. These combs should be taken out, when the honey crop is being removed, and replaced with combs of sealed honey to provide a full super of honey for the winter period. Others set aside supers containing only 10 to 15 pounds of honey, and give them to colonies in the spring when they need food. These supers are left with the colonies and become the first supers used for the new crop.

When combs of sealed honey are used for feeding, care should be taken to see that disease is not present. These reserve combs may contain

honey that is dark colored or strong flavored and of low market value. If the bees do not use all of this honey, the remaining combs should be removed before the flow begins to prevent the undesirable honey from being mixed with the new crop.

When honey is not available, the best food is sugar sirup made from pure cane or beet sugar. Sugar sirup is easy to make. Usually a mixture is made of 1 part sugar to 1 part water by volume, the sugar dissolving readily in hot water. The water is brought to boiling and removed from the source of heat, and the sugar is then added, stirring until it is dissolved. Heating the sugar and water together is satisfactory if the mixture is stirred constantly. However, the sirup should not be boiled over direct heat as it will caramelize slightly and will not be satisfactory as feed for bees. Sometimes sirup made in this manner will crystallize in the containers. This may be prevented by adding to the prepared sirup a tablespoon of tartaric acid for each 100 pounds of sugar used.

Those having a steam boiler use steam to heat the water. The sugar may then be added at once to the water and boiled vigorously without danger of caramelization because the steam agitates the solution. When the sirup is cool, it is ready for use.

Some use a thinner sirup in spring and a heavier one in fall. Some beekeepers feed a thin sirup outdoors in metal containers with floats so the bees will not drown in the sirup. This is not good practice because all colonies, including those belonging to other beekeepers, may take the sirup whether they need it or not. In bad weather bees will not be able to visit the feeder and thus may starve with food just outside the hive. During a dearth, the exposure of the sirup also incites robbing.

*Stimulative feeding,* or feeding to increase the activities of the colony, is practiced by some beekeepers who give a thin sirup to the bees regularly until the honeyflow begins. This sometimes results in increased brood rearing; at other times, with reserve stores in the hive or a small amount

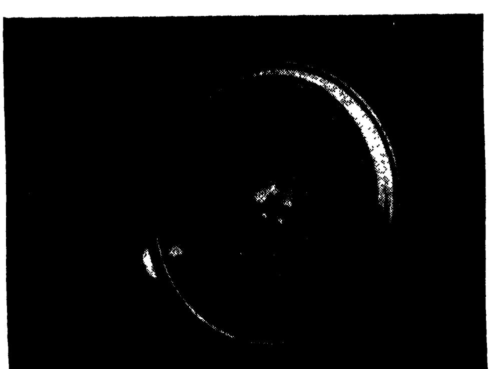


FIGURE 107. A 10-pound, friction-top pail with several small holes punched in the lid makes a handy feeder.

FIGURE 108. The division-board feeder at the side of the hive is convenient to use and holds about 10 pounds of sirup.

of nectar available in the fields, stimulative feeding appears to be of little value. It is probably better to feed the bees when they need it rather than for stimulation, and even then not to give too large an amount of food at one time.

When there is no nectar available, the amount of feed that bees will take is almost unlimited. Colonies will store the sirup just as they do nectar, even swarming at a time when there is not sufficient nectar from natural sources for a livelihood. Obviously, such overfeeding is a waste. On the other hand, beekeepers may feed too little and use feeders of small capacity which do not give the bees enough feed.

The best feeder is a 10-pound, friction-top pail (Fig. 107), or a screw-top jar of large capacity, having two or three holes punched in the center of the lid. Some beekeepers punch holes over the entire lid for faster feeding but, if such feeders are not placed exactly level, the last of the sirup may leak out.

When filled with sirup, the feeder is inverted over the open hole in the center of the inner cover or, if an oilcloth is used, the feeder may be placed at one corner where the oilcloth is turned back. An empty hive body or super is used to surround the feeder and the hive is then covered. In early spring or late fall, the feeder may be inverted directly over the combs above the cluster of bees with a packing of cloths around it. If the sirup is warm (not hot), it will be taken more easily and quickly.

Many prefer to use the division-board feeder (Fig. 108) which holds about as much sirup as the 10-pound pail. It is made the size and shape of a hive frame, supported at the top by projections like the ends of the top bar of the frame. The sides of the feeder are made of plywood, pressed wood, or similar material, or the feeder may be made entirely of metal. In any case it should be watertight; melted paraffin may be used if necessary to coat the inside of the feeder. The division-board feeder is hung in the hive at one side; sometimes it is left there permanently where it is

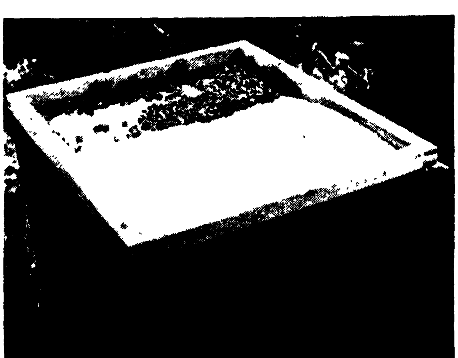


FIGURE 109. Here the bees are being fed dry granulated sugar in a special feeding device with entrance at the rear.

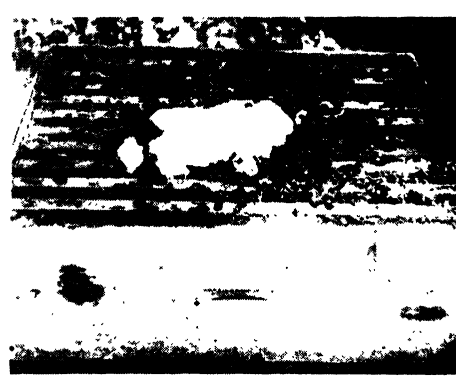


FIGURE 110. Sugar candy also can be fed in this manner directly over the brood area and on top of the frames.

always ready for use. The feeder is open at the top to provide entrance for the bees, and contains floats or a V-shaped piece of screen wire to enable them to take the sirup without drowning in it. There are other types of feeders, but the 10-pound pail and the division-board feeders are used most commonly.

When there are no containers available for feed, empty combs may be filled by dipping them in a container of sirup. After the combs have dripped free of excess sirup, they may be given to the colonies, preferably late in the afternoon.

In the spring, unless a colony of bees is on a starvation basis, a 10-pound feeder of sugar sirup at one time is enough, and this amount should last at least a week. When nectar sources become available to augment the feed, a 10-pound feeding may last as long as 2 weeks. A colony on a constant feed basis usually does not require over three feedings in spring before the beginning of the main honeyflow.

When taking feed to outyards, large containers, such as steel drums provided with a faucet for filling the feeders, are ideal and are easily carried in the truck. Sixty-pound cans are satisfactory but less substantial.

When bees fly freely and the weather is warm, it is often possible to feed them dry sugar (Fig. 109) which may be spread on the inner cover with the hole open or on the oilcloth with one end turned back. Five pounds of sugar will last longer than 10 pounds of sirup, particularly when bees have access to minor sources of nectar before the honeyflow.

Sugar candy is sometimes used for emergency winter feeding (Fig. 110). The candy is prepared by adding 12 pounds of sugar to a quart of boiling water, stirring well, and allowing to simmer for 15 minutes. Then add a little salt, a teaspoon of cream of tartar, cool partly, stir vigorously, and pour into dishes. When the candy has set, a dish of it may be inverted directly over the winter cluster and the hive closed.

Honey gathered late in the season may often be unsuitable for winter stores because the bees do not have opportunity to ripen it thoroughly before they cluster for winter. When this occurs, they may become loaded with indigestible material; if they are unable to void this in flight, they become restless and many bees die within the hive. This can be largely avoided if a 10-pound feeding of sugar sirup is given to each colony in the fall after brood rearing has ceased. The bees will store the sirup in the combs immediately around their clustering space where it will become the first food used in winter. Usually they will not reach natural stores until late in winter or in early spring when there are more frequent chances for flight.

## Providing Water for Bees

Honey bees use quantities of water to dilute the brood food and to aid in cooling the hive by evaporation. It may some day become apparent in

FIGURE 111. A keg with a dripping spigot provides water for the bees on the inclined board. (*Photo courtesy J. R. Schmidt*)

practice that water should be given bees in a feeder inside the hive where they may obtain it without having to fly in search of it in inclement weather.

Particularly in the South, large amounts of water are gathered by bees and placed in convenient, temporary storage places in the combs, especially in burr combs and other comb constructions between the hive parts and along the top bars. This water is used to cool the hive through evaporation.

The need for water in substantial amounts for brood-rearing purposes is so great that the bees will obtain water from any outside source, frequently going to stock watering tanks, pumps, bird baths, lily pools, or similar places where they often become bothersome. This is particularly true in the spring and during periods when nectar is not plentiful in the fields. Bees may collect water from undesirable sources as well as from sources of clean water. Often they prefer salty water. Betts[2] states that there is a possibility that salt to the amount of 1 part to 200 may be liked

[2]Betts, Annie D. 1932. Salted water. *Bee World* 13:13–14.

by bees but she hesitates to say whether it is because the bees enjoy the flavor or because it makes the water more viscous and easier to suck up.

If colonies are not located near natural sources of water, some sort of watering device becomes a necessity. It is best to provide water that does not stand in a container with a still surface but rather drips from a container onto a sloping board or trough where it is collected by the bees as it flows along (Fig. 111). There is a strong suspicion that the spread of Nosema disease is often aided by water sources which may become stagnant, such as low seepage places in the vicinity of an apiary.

If the bees are not attracted to the watering place immediately, small cotton balls soaked in anise may be hung around the watering device. This attracts the bees and aids in starting them to obtain water from the place provided, after which they will continue to take water there readily.

## How to Make Increase

A common source of increase is the swarms which issue from the colonies in the apiary. Swarming, however, is not desirable because it creates a division of the working force of the colony. Neither the swarm nor the colony from which it came will produce as much honey as the original colony would have done. Nevertheless, a swarm successfully hived does constitute a new colony.

There are ways to secure increase from the bees on hand without depending on swarming. In spring, colonies that are not as strong as others and which may be spared from honey production can be divided into two-comb nuclei and each nucleus given a new queen. It is best to move

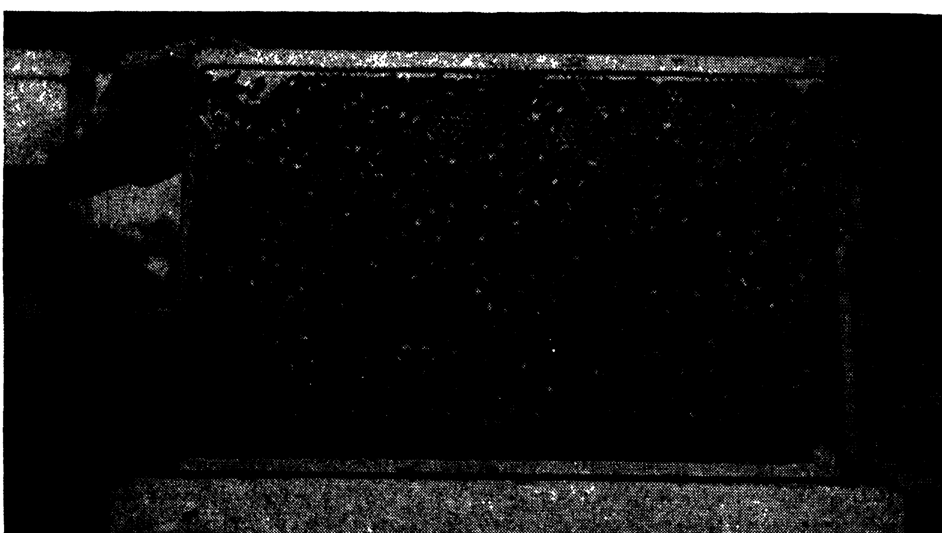


FIGURE 112. A beautiful comb of worker brood—the kind for use when making increase.

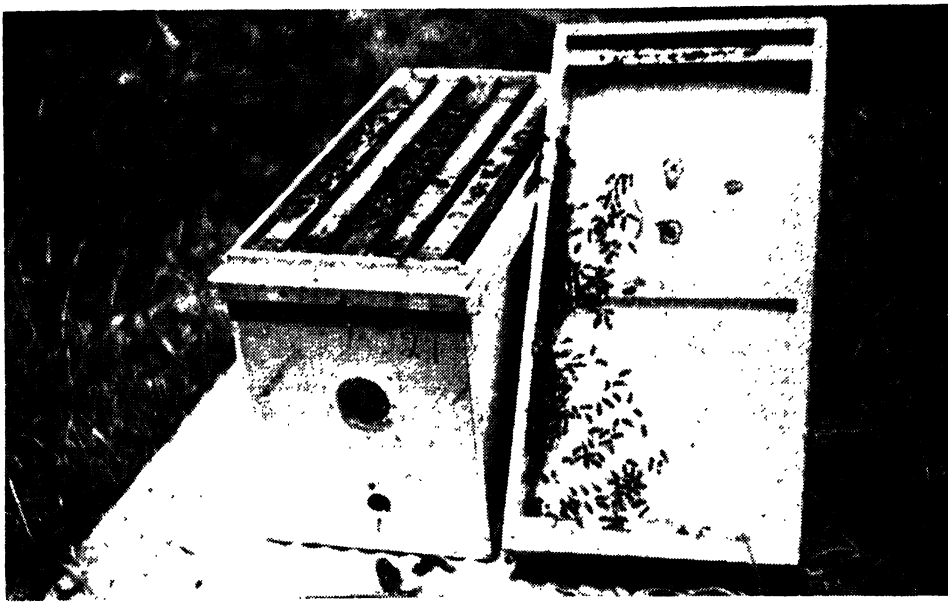


FIGURE 113. The transport box, or nucleus box, filled with combs of brood and bees, ready to be covered and taken to a new location.

the newly made colonies beyond flying distance of the apiary in which they are formed so that field bees will not return to their old location, thus depleting their flying force. These nuclei will build to colony strength during the season. Each division may be helped greatly by giving them additional combs of brood and bees when the opportunity presents.

Those who keep bees in two-story Langstroth hives frequently make increase by separating the hive bodies when both of them are occupied with brood. The queenless hive is given a new queen. In most seasons neither part will produce as large a crop as the undivided colony. However, if there is a long period between the time the division is made and the beginning of the main honeyflow so that there is a large increase in the population of each part, both divisions may make a good crop.

A slow but convenient and relatively sure way to make increase is to shake most of the bees from one colony into a hive with combs, leaving the queen and some of the young bees with the original combs. Put the original hive in the place of any other strong colony in the apiary, moving the strong colony to a new location. The bees shaken from the first colony are then placed in the original location and provided with a new queen. Thus, from two colonies, a new one is obtained.

Before the honeyflow when colonies are at their peak in population, it is possible to remove combs of brood and bees from strong colonies without impairing their strength. Combs of emerging brood are preferable (Fig. 112). The addition of empty combs or foundation to these strong colonies, to replace the combs of brood that are taken for increase,

frequently reduces the tendency to swarm. In removing combs of brood for this purpose, never reduce the strength of colonies sufficiently to impair their ability to gather a maximum honey crop.

The removed combs of brood and bees are placed in transport boxes (Fig. 113) and the boxes, when filled, are taken to a new location preferably two or more miles away. The boxes are opened for flight and each is given a new queen. When the queens are accepted and laying, the new colonies may be transferred to hives.

Toward the end of the summer honeyflow when the major part of the crop has been gathered and there is still a period of about 3 months in which nuclei can grow to colony strength, colonies that are not doing well in gathering a crop of honey may be divided into nuclei. The supers, which may be on these colonies, are removed and given to other colonies. Each of the selected colonies is broken up into two or three nuclei. Each nucleus is hived in a transport box, removed to a new location, and a new queen is introduced. Later the nuclei may be transferred into hives. If these divisions are made sufficiently early in the year, they will make full colonies by late fall.

Particularly toward the end of the summer honeyflow when they no longer will be needed for gathering nectar in the fields, bees may be shaken into package cages from any strong colonies. These packages may be taken to a new location, given a queen and installed in the same manner as package bees received from the South.

In making increase, the possibility of robber bees invading the new colony should always be kept in mind. It is best to make increase when robbing is not apt to occur and entrances to the new colonies should be reduced as a precaution. The satisfactory growth of the new colonies is almost impossible when they are bothered constantly by robber bees; and the harassed colonies often will be completely wiped out by the robbers.

## Package Bees

The first advertisements offering package bees for sale appeared in the spring of 1913. Previous to that time, beekeepers found it necessary to raise queens and to make divisions from colonies at hand for replacing those that failed to survive, and for making increase. Often this required the sacrifice of all or part of the honey crop from the colonies that were so divided. Because of the many difficulties involved, the extent of commercial beekeeping was less than it is today.

The sale of bees by the pound has now grown to large proportions and package shippers located in the South and in California have developed an extensive industry. Package bees are usually shipped by express in wood-and-wire cages into which are shaken two, three, or more pounds of live bees. Northern beekeepers also go south with their own trucks to secure package bees and take them north in the spring. Each package is

provided with a can of sugar sirup to supply the bees with food. A queen in a mailing cage is suspended inside the cage usually from the top. For further particulars see Chapter XXI, "The Production of Queens and Package Bees."

Strange as it may seem, in the North where there is a long build-up period previous to the main honeyflow, the 2-pound package is preferred. However, in localities where the period before the flow is short, the 3-pound package is preferred. Orchardists, seed producers, and vegetable growers often use larger packages for pollination purposes.

Where only increase is wanted and the beekeeper does not figure on obtaining surplus honey during the season at hand, it is possible to buy package bees later in the season at lower prices. With proper care these later packages will grow into full colonies by fall.

Where winter conditions are severe and there is difficulty in wintering bees except at high cost, as in the far North, many commercial beekeepers prefer to kill their bees at the end of the producing season and to replace them with packages the following spring. Such practice has the advantage of a short working season, nearly all of the honey may be extracted, the hives may be stored away out of the weather where they can be placed in condition for the next season, and the combs can be sorted better. On the other hand, the best colonies, if wintered in a building or a cellar with close attention and intelligent care, may be divided in the spring. These divisions will restore at least a part of the original number of colonies and the balance can be replaced with package bees. Nevertheless, the cost of wintering is usually high in northern latitudes.

### Preparing to Receive the Package Bees

To determine the number of packages which will be needed in the spring, estimate the number of colonies that ordinarily may be lost in winter. Add that figure to the number of empty hives on hand in the fall to make a total count that can be ordered from the package-bee producer in early fall or winter. This makes it possible to obtain packages from preferred breeders and to choose a shipping date to suit one's conditions.

Package bees should arrive 8 to 12 weeks before the beginning of the first main honeyflow. It is also desirable to have bees arrive during a time when nectar is being gathered from minor sources, such as fruit bloom, so that the conditions for hiving packages will be ideal and they will be started into colony life with the least attention and trouble.

It is good practice to set aside combs containing pollen and honey from healthy colonies for use in starting packages the succeeding year. These combs may be distributed in the hives intended for the packages and the remaining space filled with empty drawn combs or with frames containing full sheets of comb foundation.

When outyards are operated, it is sometimes better to hive packages near home where they can be cared for with the least expense. Here they

can be managed carefully so they will reach full strength together, when they may be moved to the outyards just before the main honeyflow. Weak or indifferent colonies can either be united or left behind for further attention.

It is a good plan to notify your express agent of the date when you are expecting a shipment of bees (Fig. 114). When the packages arrive at the express office, they should be examined carefully to determine whether or not there has been loss in shipment. Packages in which the bees are all dead and those in which the percentage of dead bees is high should be reported on the express receipt so the shipper will have recourse for damage claims. Replacement of the bees or credit for the loss may be requested of the shipper as the customer decides. The shipment should always be accepted, however, because refusal complicates matters. Serious losses in shipment are not frequent.

It is best to hive packages in the late afternoon or toward evening so that the bees will not fly too freely before the end of the day, but will become established to a certain extent overnight. Cool, cloudy weather with a temperature even as low as 32° F., particularly without wind, is ideal for hiving package bees.

Unless conditions are ideal for hiving packages on their arrival, it is good practice to store them in a dark, quiet place with a temperature of 50° to 60° F., such as a cool basement. Before placing them in storage, the packages should be fed heavily with sugar sirup brushed or sprayed on the wires of the cage. Particularly when the weather is not satisfactory,

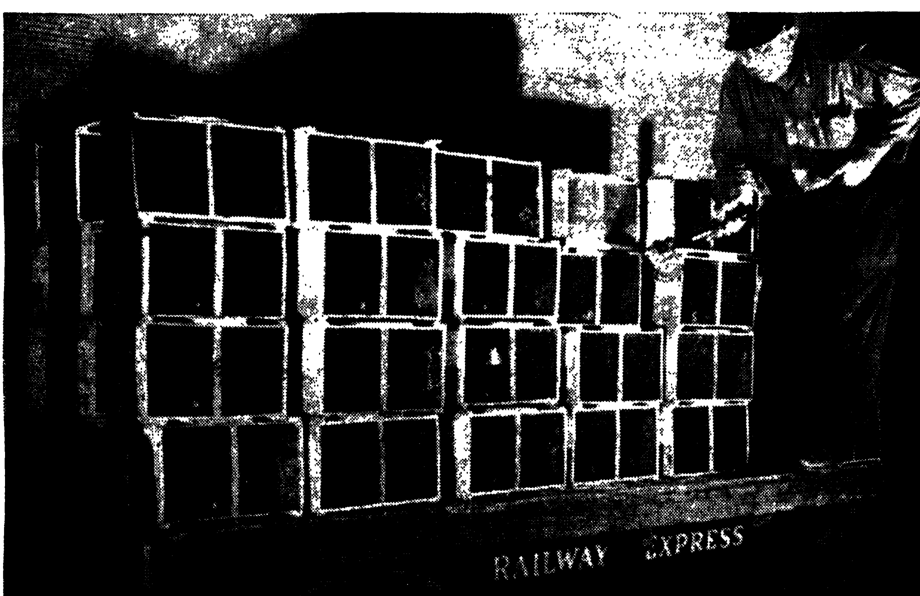



FIGURE 114. A shipment of package bees rushed by railway express from the sunny South to a northern beekeeper.

they may be left in storage for a day or two before hiving them. The storage period tends to put the bees in better condition for hiving; they cluster together quietly, are less excitable when placed in their hives, and seem to be intent on beginning comb building.

### Installing Package Bees

A satisfactory procedure for hiving the package bees is to set the individual pail of feed and a package behind each prepared hive. A good plan is to provide each hive with five combs leaving the remaining space empty, arranging the combs at one side of the hive. In the Dadant apiaries, an oilcloth, or similar material, over the frames of the hive is preferred, even when using an inner cover.

The entrance of each hive should be reduced. A good entrance reducer is a thin slat with a two-beeway opening in the center which is lightly filled with green grass. If a top entrance is used, the lower entrance should be closed and the top entrance lightly filled with grass. As the grass dries, the bees gradually remove it. If they are not disturbed, package bees will not fly freely until they have become accustomed to their new quarters.

It is desirable to feed the bees in the cages again before they are released, using a sugar sirup sprayed or brushed on the wires of the cage. Two-pound packages will usually take a half pound or more of sirup, half sugar and half water, to the feeding. The usual practice is to feed the bees until they will take no more.

However, inasmuch as the purpose of this feeding is to quiet the bees rather than to give them food, packages of bees may be hived just as effectively by spraying them or sprinkling them with warm water (Fig. 115), and there is less tendency for robbing to occur than when sprayed with sugar sirup. When wet with water, the bees are unable to fly and it takes several hours for them to dry. This gives them plenty of time to become organized and the result is just as good as when sugar sirup is used.

When everything is in readiness, the bees in each package are shaken down into the bottom of the cage (Fig. 116) and sprayed with warm water, the feeder can is removed (Fig. 117), and the queen cage taken from the package (Fig. 118). The feeder can then is set over the hole in the package while the queen cage is prepared for introduction.

Some prefer to allow the bees to release the queen from the cage in which she is shipped. With this method of queen introduction, the usual procedure is to remove the paper cover over the hole of the candy compartment and either to hang the queen cage with the candy end up between the combs, or to lay the queen cage face down on the top bars of the frames or face up on the bottom board. The hive bees later will eat out the candy and effect the release of the queen.

When package bees are hived on combs, it is more satisfactory to release the queen at once. The cover over the open end of the queen cage is removed and the cage is placed screen side up under the bottom bars of

FIGURE 115. The bees in the package are wet with warm water to prevent them from flying freely when the package is opened.

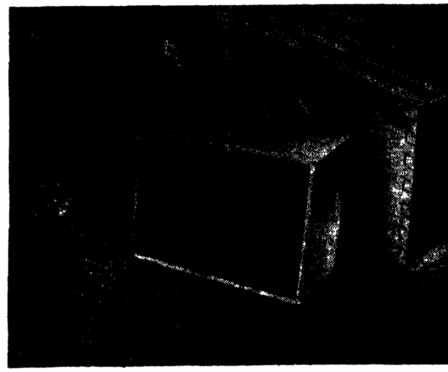


FIGURE 116. The cage containing the bees is jounced on the ground to jar the bees onto the bottom of the cage.

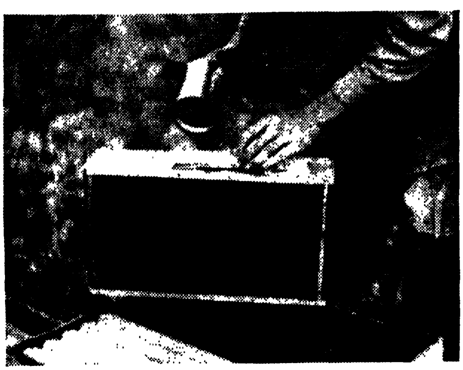


FIGURE 117. When the feed can is removed, place the wooden cover over the open hole to prevent bees from coming out.

FIGURE 118. Next the queen cage is removed, shaking the bees clinging to the cage back into the package cage.

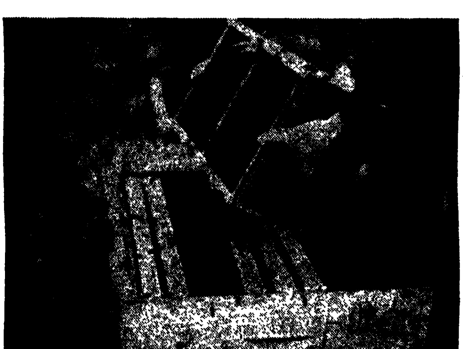


FIGURE 119. Shake and pour about half of the bees between the frames where the queen cage has been suspended. Then carefully push the frames together.

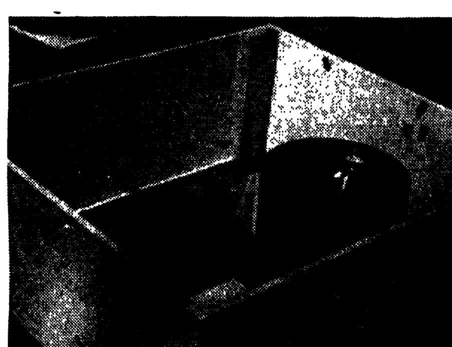


FIGURE 120. After the feed pail has been inverted over the frames and an empty super placed on top of the hive, it is ready to be closed.

three of the combs in the hive, the remaining two combs being pushed aside to provide a space into which to shake some of the bees from the package onto the bottom of the hive (Fig. 119) where they will quickly find the queen cage or the queen as she comes out. The two combs, temporarily placed at one side, are then pushed up close to the others, a piece of wood or a stick is laid on the bottom board in the empty space at the side of the five combs, and the package with the remaining bees is placed there with the feed hole up.

The cloth cover or inner cover is then placed over the top of the hive and the feeder pail inverted over the hole so that the bees have ready access to the feed. An empty super or hive body, or a special rim, is placed on top (Fig. 120) and the hive is closed. If the combs contain considerable pollen and honey, often only this one feeding is necessary. Should the feed in the combs become exhausted, feeding must be resumed or combs of honey must be supplied until the colony is able to gather sufficient nectar and pollen to provide for its food requirements.

## Management of Package Bees

There comes a critical time in the progress of the package colony, usually about 3 weeks after it is hived, when the new brood produced from the eggs of the queen reaches a relatively high point in proportion to the number of adult bees. Many of the bees that came with the package will have died and no young bees will have emerged. It is often at this time that supersedure of the queen occurs, probably because the population is out of balance. This can be largely overcome by giving the package colony a comb of emerging brood and bees from a healthy colony, placing this comb next to the brood combs in the package colony. This should be done about 2 weeks after the package is installed; colonies so treated will gain surprisingly in strength.

When packages are hived on drawn combs with plenty of food and with a favorable season, they will often develop into full colonies in time to gather some surplus honey the first season. In the North, packages will produce good crops during the first season due to the long build-up period.

Supersedure in package bees is often a critical problem. Sometimes supersedure occurs because of too frequent handling of the new colony and sometimes because the queens are inferior or because they are infected with Nosema disease. Breeding stock also is a factor in queen losses inasmuch as some queens are not as good as others in the quantity or the quality of their brood, and thereby influence the amount of surplus honey secured.[3] A heavy annual replacement of queens suggests that each apiary should have a reserve supply of laying queens in nuclei ready to replace those which show signs of being inferior, thus making it possible to prevent interruptions in brood rearing during the active season.

[3]Farrar, C. L. and C. W. Schaefer. 1939. Influence of stock on supersedure or loss of queen bees. *U.S.D.A. Circ.* E-473.

If the combs on which the package is hived do not contain an abundance of pollen in the cells or if foundation is used in hiving the package, it is a good plan to make sure that the bees have access to a pollen supplement or a pollen substitute unless natural pollen is available in abundance and the weather is such that bees can gather all the pollen they need. For further information on pollen supplements, see Chapter XIV, "The Overwintering of Productive Colonies."

Haydak and Tanquary[4] have given a number of formulas for the preparation of pollen substitutes. A good formula consists of a mixture of 3 parts by weight of brewer's yeast, of the type fed to animals, and 6 parts of expeller-processed soybean flour, moistened with sugar sirup made of equal parts sugar and water. Mix this with the hands until the material is of a soft, pasty consistency. Cakes of this pollen substitute may be placed over the top bars of the frames directly over the brood (Fig. 121). Feeding pollen substitute every 10 days for as long as the bees will take it, will help the packages grow materially. The bees take the substitute as long as they need it. When natural pollen is available they will not take it readily; frequently they will not take it at all.

The chance of shipping package bees from diseased colonies in southern locations is slight. Inspectors in the South are active in checking the apiaries of package shippers and every precaution is taken to be sure that bees are taken only from healthy colonies. There have been instances of disease in the apiaries of shippers but such apiaries are quarantined until a clean bill of health is available. A good method of prevention of disease in package-bee colonies is the feeding of 1/4 teaspoon of soluble sodium sulfathiazole, or the common half-gram tablet, in each 10-pound pail of sirup given to the packages at the time they are hived.

In the spring, colonies with good queens, but too weak in numbers of worker bees to grow rapidly, may often be helped by giving each of them a queenless package of bees. Queenless packages are often worth the investment if received sufficiently early to help the weak colonies. They may be united with the bees in the colony by placing the opened package cage on top of the inner cover, protected by an empty hive body or super. The cage opening should be near the open hole of the inner cover or the turned-back oilcloth. The colony should not be disturbed for a few days until the union has been satisfactorily accomplished. Two-comb nuclei and comb packages may be bought for replacement or for increase. Shipments of bees on combs are barred by some state inspection laws because of the possibility of disease. The nuclei and comb packages in reality are small colonies. On arrival, they may be set out where they are to be hived, a flight hole provided, and later transferred to hives. Provided with a full set of combs they often grow faster than combless packages, probably because they have a more balanced population and because of the brood

[4]Haydak, Mykola H. and Maurice C. Tanquary. 1943. Pollen and pollen substitutes in the nutrition of the honeybee. *Univ. Minn. Tech. Bull.* **160**.

FIGURE 121. A cake of pollen supplement or pollen substitute given in this manner helps the package colony to grow. (*U.S.D.A. photograph by Forsythe*)

which continues to mature, while the combless package is entirely without brood when it is received.

Combs or frames of foundation should be added to the new colonies as they continue to grow. The entrances should be enlarged as the colony needs additional ventilation and is able to defend itself from marauders. Each colony also should be kept supplied with an abundance of food until it is able to obtain sufficient food from natural sources. When the new colonies have reached sufficient strength to completely occupy the hive bodies they are capable of occupying supers and of storing surplus honey whenever there is a honeyflow. Their management thereafter will be the same as that of any other established colonies.

## Queen Management

It would be difficult to discuss the queen bee and all of her relationships to the colony in a single subject division. Consequently, the methods of finding and marking the queen, ways of judging and introducing the queen, and methods of using two queens in colony management are discussed separately. Probably no phase of beekeeping is more frequently discussed than the management of the queen nor have so many different ways been devised to conduct management successfully. In the following pages are given those methods which are used most frequently and with the greatest degree of success.

### How to Find the Queen Bee

It is much easier to find queens in the early part of the season when the population of the colony is not large and the amount of brood is small. Choose a time when there is sufficient nectar available to prevent robbing. When brood rearing is expanding in the spring, the queen is apt to be in the upper body of a two-story colony. During the honeyflow, she is usually in the lower body. At this time, considerable labor is required to reach the brood nest because supers must first be removed, and there are so many bees present that it is difficult to find the queen. In the latter part of the fall honeyflow when most of the supers have been taken off and the colony is not so large, it again is relatively easy to find the queen.

When trying to find the queen, easy motions and the use of as little smoke as possible are advisable. The queen will be so occupied with her duties that she will pay little attention to the operator. Remember that the queen is seldom on combs which contain little or no brood. Remove one or two such combs and begin to work slowly toward the center of the

FIGURE 122. The queen here is searching for suitable cells in which to lay her eggs. Good queens deposit eggs from one end bar to the other, and from top bar to bottom bar, whenever open cells are available. (*Photo by Milledge Murphey, Jr.*)

brood nest, or separate the combs in the middle and work either way from the center. When removing a comb from the hive, look quickly for the queen on the side of the comb next in view within the hive before examining the one which has been removed. Two people working together on opposite sides of the hive usually find the queen more quickly.

The queen is usually on combs containing young brood and eggs (Fig. 122) and it is unlikely that she will be found on combs of sealed brood or honey unless she has a tendency to run from the operator. Bees of some colonies accompanied by the queen tend to travel away from the operator, even to the point of reaching the hive walls or the bottom board where the queen will remain hidden in a cluster of her own workers.

When there is little chance of robbing, combs may be set outside the hive in their proper order after they are examined, and they should be returned in the same order when through. Watch carefully. Do not try to see the whole surface of the comb but look only for the queen. She will usually be found on the first examination. If not, the brood combs may be put back into the hive in separated pairs, the hive closed for a few minutes, and then reopened. Each pair of combs may then be examined in succession, looking first for the queen between each pair of combs.

It is sometimes necessary to use special methods to find the queen. Perhaps the easiest way is to set the hive body of brood and bees to one side, place a hive of empty combs on the bottom board, cover it with a queen excluder, and place an empty hive body on top of the excluder. Shake the bees from the combs of the original hive into the empty body on top, replacing the combs in the hive from which they came. After all the bees are in the empty body, the workers will run through the excluder onto the combs below but the queen, unable to pass through, will eventually come into view above the excluder. A similar method is to place a strip of queen-excluder zinc over the entrance of the hive, shaking the bees in front of the hive.

In looking for the queen in a two-story colony, put a queen excluder between the two bodies, examine the upper body first, and then the lower one. The queen cannot go from one hive body to another because of the excluder. Sometimes the two bodies are set apart quickly and then covered, each one being worked separately to find the queen.

It is not necessary to see the queen to know that she is present in the hive. If there is brood in all stages of development in satisfactory quantity and arrangement and the colony's adult population is well maintained, there is seldom any reason to search for the queen.

Queen bees which are marked in some manner are found more readily than those which are not marked. Queens of the Caucasian and Carniolan races are more nearly the same color of the worker bees and are difficult to locate unless the queens are marked.

Marking fluid may be placed on the center of the thorax of the queen between the two wings. A good material to use is nail polish or a quick-

drying enamel. The fluid is applied with a small brush while holding the queen with the fingers, and it is well to allow the material to dry to some extent before releasing the queen. Red, green, orange, and bright blue are satisfactory colors. Some use colors to designate years, source of stock, or other factors. The bees apparently pay little attention to the marking which usually lasts during the lifetime of the queen.

Although it does not help in finding the queen, the most common way of marking the queen is to clip her wings on one side of the body (Fig. 123). Usually the wings are clipped on the right side if the queen is introduced in an even-numbered year and on the left side in an odd-numbered year. If a queen is found later with unclipped wings, it is known that she is a supersedure queen or that the queen originally introduced was not accepted.

## How to Judge a Queen Bee

Like any other animal, the queen bee has definite physical characteristics (Fig. 124). Inasmuch as the queen bee lays the eggs, she is the mother of the colony, and her physical conformity must provide for this important responsibility. Not only may she be judged by her physical qualifications for the work she is expected to do, but also by the results of her labor.

The queen should have a gently tapering abdomen particularly large and full along the sides. She should be evenly colored and have a large

**Figure 123.** The queen is carefully held between the thumb and the index finger while clipping the wings on one side. (*Photo by Milledge Murphey, Jr.*)

thorax. Such a queen usually has good egg-laying capabilities. A queen that is short, stubby, off-colored, erratic in movement, or whose body tends to fall away from the hips in a "rat-tailed" shape with a point at the end of the abdomen is not desirable.

Sometimes a queen with good body conformity, however, does not lay well. When a queen has established three or four combs of brood, the efficiency of her work may be determined. If the combs are well occupied with concentric circles of brood of similar age (Fig. 125), the queen should be satisfactory. The queen that lays steadily, producing brood of an even character throughout the season and until late in the fall, is a good queen.

It takes a large population of field bees to gather a crop of honey. Queens that fill the cells of the combs rapidly several weeks before the beginning of the honeyflow and maintain their egg-laying rate through the honeyflow period will produce a maximum number of bees to gather the crop. Queens that lay slowly before the flow may later develop a maximum colony but they will do it on the honeyflow rather than before, and the colony will gather less surplus honey.

A good queen will place her eggs in the exact center of the cell bottom, each egg usually slanted in the same direction. The eggs will be laid symmetrically, starting usually a little above the center of the combs and spreading out evenly in all directions.

A good queen may also be judged by the behavior of her progeny. The colony should be a good honey producer and not inclined to swarm. The bees should be gentle and evenly marked. Colonies should winter well and should provide themselves with an abundance of stores of honey and pollen placed properly in the combs.

Replacing poor queens in early spring and fall is a valuable practice. Queens introduced in the spring will provide vigorous mothers for the production of large colonies before the honeyflow. Those introduced in the fall will provide the colonies with many young bees for winter and will be able to carry the colonies successfully through the honeyflow the succeeding season.

Some beekeepers contend that queens should be replaced each year but it seems foolish to replace queens on a calendar basis. Under some conditions, queens cannot possibly exhaust their powers of egg laying in a single season. Under other conditions, queens will actually wear out in preparation for and during a single honeyflow period. The best way to practice requeening is to replace poor queens whenever they are found. Poor queens may be noted when one works with colonies and the hives marked so that those colonies may be requeened at the first favorable opportunity.

The age of the queen does not determine her performance. Young queens are often poor from the very start of their egg laying; sometimes queens lay well for several seasons in succession. The bees apparently know when a new queen is needed. They may supersede the old queen

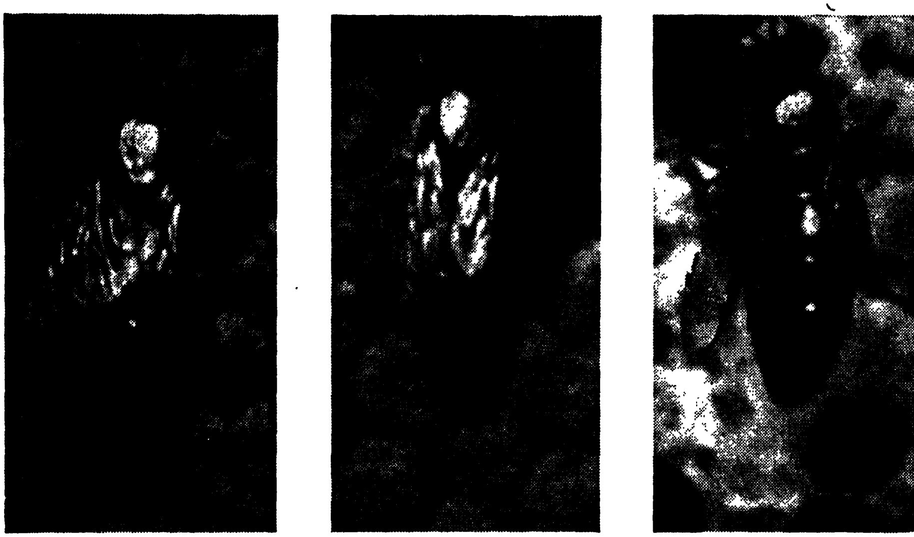


FIGURE 124. The queen at left is large, long, and well proportioned, having great depth to the abdomen. The queen in the middle is satisfactory but represents a medium-size queen. The queen at right is a stubby type. Medium-size, stubby-type, and rat-tail queens seldom have the egg-laying capacity of a queen of the type illustrated at left. (*Photo courtesy Division of Bee Culture*)

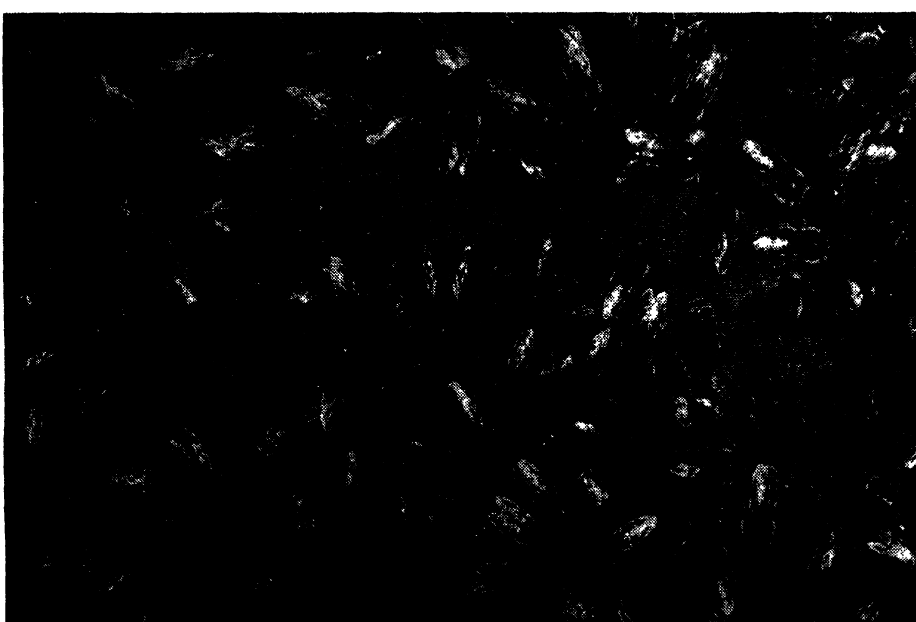


FIGURE 125. Worker bees covering an area of good worker brood—the work of a good queen. Such solid areas of brood of similar age, plus the quantity of the brood, is the measure used by most beekeepers for judging the queen. (*Photo by Ben Knutson*)

by their own efforts and the beekeeper may not know that the old queen has been replaced. Some colonies will replace their queens several times a year, others may not replace them more than once in several years.

It is not unusual for the beekeeper to find two queens in the same colony at one time, one of them the aged mother and the other the supersedure daughter. If the beekeeper sees only the old queen and judges her by physical appearance, he may try to introduce a new queen to a colony which already has a young laying queen. This will result in the loss of the queen that is being introduced.

### How to Introduce the Queen

The proper method of introducing queens is a much discussed subject. There are many methods used, most of them working under certain conditions and failing under others. The failures are likely due to an incorrect understanding of the basis for successful introduction. The theory of colony balance in relation to queen introduction was defined first by Sechrist.[5] According to this theory, the queen to be introduced must be in about the same condition with respect to egg laying as the queen which is to be removed. This appears to be the requirement for ready acceptance of new queens, and when this balance is provided introduction is easy by almost any method. If the balance between the two queens is not equal, introduction will usually fail.

In the natural processes of brood rearing, the colony will have little brood in the spring and as the colony grows the amount of brood increases until it reaches a large amount just before or in the beginning of the honeyflow. Brood rearing will taper off between flows, and in the fall it is at a low point. Young queens, therefore, may be introduced easily in a nectarflow in the spring or in the late fall when egg laying is at a minimum without any special attention being paid to whether the new queens may have begun their egg laying. The queen of the colony and the young queen are approximately in balance with respect to their egg-laying condition.

If a queen must be introduced when there is considerable brood in the colony, and the queen of the colony is daily depositing eggs to the best of her ability, then the young queen to be introduced should also be laying eggs daily to be in balance with the queen in the colony. Thus, the new queen must begin her egg laying elsewhere before introduction. This may be accomplished by first introducing the queen into a nucleus where she may be kept until she is laying well.

The queen also may be placed in a reservoir while still confined in her cage where she is fed by the worker bees and stimulated to fitness. A reservoir for conditioning queens and for holding them until they can be used in requeening can be made by establishing a nucleus of several combs of brood and bees without a queen in a convenient hive or in a

[5]Sechrist, E. L. 1944. *Honey Getting*. Hamilton, Ill. American Bee Journal. p. 115.

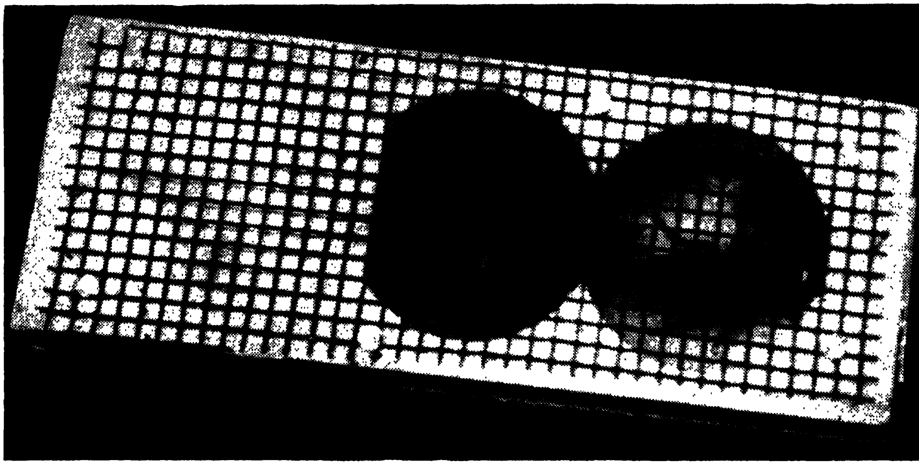


FIGURE 126. Notice the queen bee in the center of the open hole of the queen-mailing cage at right. This is the typical three-hole cage, the covered hole at left containing queen candy.

transport box. A colony of bees also may be used as a reservoir without removing the queen.

Whether using the queenless nucleus or the queenright colony for a reservoir, the attendant bees are removed from the cages containing the new queens and the cages placed in a frame adapted for the purpose of holding them. One should make sure that the candy compartments are protected so that the bees will not eat their way into the queen cages. During confinement, the new queens will be fed by the bees, and they will increase in size and begin to lay eggs about their cages. The queens may be kept in the reservoir a week or two before they are used, and the reservoir should be kept in condition by frequent additions of brood and bees. The reservoir can be carried from one yard to another when requeening, and brought home each night.

When the time comes to introduce the new queen into the colony to be requeened, the introduction ordinarily is made by using the shipping cage containing the young queen (Fig. 126), whether she is introduced directly upon receipt from the breeder or taken from a reservoir or nucleus. First, remove the old queen from the colony that is to be requeened. The safest plan when using the queen-mailing cage is to remove the attendant bees, providing this already has not been done, and to remove the paper cover over the candy hole of the queen cage. The cage then is inserted between two brood combs in the colony (Fig. 127). If the weather is cool, the bees will cluster about the cage and the queen will not be chilled. In time, the worker bees will eat through the candy and release the queen.

The behavior of the queen when she is released by the bees, influences the conduct of the bees toward her. If she is rapid in motion, she may not

be accepted as readily as a queen that is quiet and slow in movement, ready to lay at once and eager for food.

Many beekeepers are overly anxious to determine whether or not the queens have been accepted after their introduction. Frequent examination of the colony, or examination in inclement weather, may result in the loss of the new queen through being balled by the worker bees. Balling occurs when the worker bees cluster tightly about the queen and pull at her legs and wings until she is badly injured and frequently killed. When a colony is examined to make sure the new queen has been accepted, if eggs are seen, the queen is there. The hive should be closed and the colony left alone.

During a honeyflow when it is desirable to keep colonies up to full strength to maintain their field force, a new queen, before being introduced into a colony to replace one that is not doing well, first must be brought into egg-laying condition in a nucleus. The old queen should be removed from the colony along with as many combs as there are combs in the nucleus. Then the nucleus with the new queen is placed in the center of the colony, the bees of both the nucleus and the colony being sprinkled with sugar sirup.

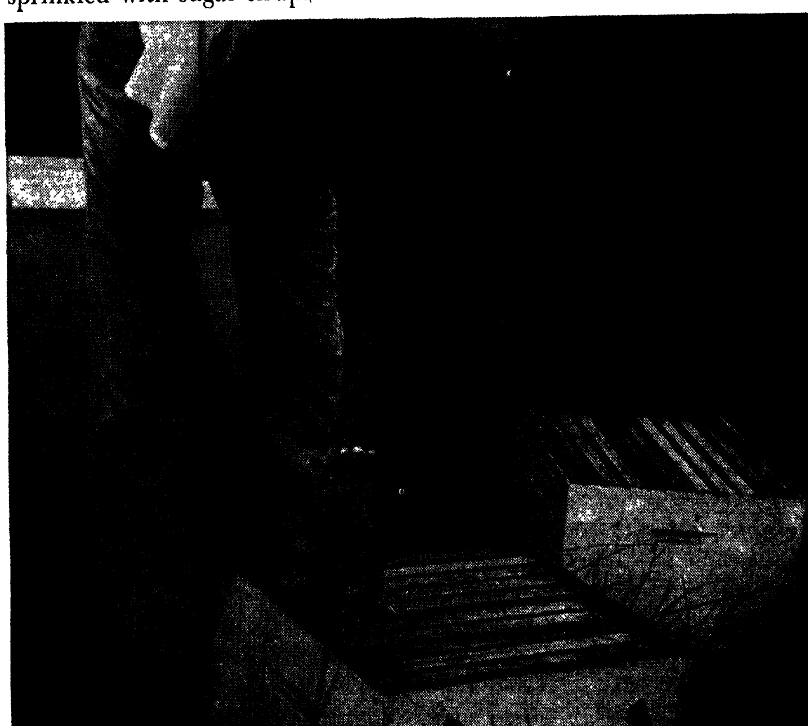


FIGURE 127. The queen cage is suspended between the frames with the paper removed from the candy hole and with the candy end of the cage up. (*Photo by Milledge Murphey, Jr.*)

Inasmuch as the egg laying of the old queen and the queen that is being introduced are in about the same balance, introduction usually is assured. The new queen will carry the colony forward without loss of honey and sometimes with considerable addition to the crop. It is suggested by Farrar (see reference No. 6 in this chapter) that a satisfactory number of nuclei to maintain in each yard is at least 10 per cent of the number of colonies in the yard. Thus, for a 50-colony apiary at least five nuclei would be established with good queens, and used in replacing queens in producing colonies when they show signs of failure during the honeyflow.

Introducing the new queen in her mailing cage directly to emerging brood and young bees is a method which seems to work under all circumstances. To accomplish this, combs of emerging brood are placed in a hive body on top of a colony, first shaking the majority of the bees off the combs so that those which remain are young bees. The upper hive body is separated from the colony by a screen, and the brood is kept warm by the heat of the colony below. The new queen is introduced by suspending the cage between these combs, as previously described, or by releasing her on the combs where she will be readily accepted by the young bees. Later, the new queen and the combs may be given to a colony to be requeened, or the nucleus can be moved to a new location and built up by the addition of more brood and bees to form a normal-size colony.

An adaptation of this plan that is generally suited to queen introduction is the use of the so-called "push-in" cage (Fig. 128). A 4-inch square of ordinary screen wire is bent along each edge and the corners clipped to form four sides, making a wire cage which can be pushed into the face of the comb. The cage should be pushed into an area of emerging brood, preferably where there are a few cells of honey for feed. It should be inserted deep enough into the face of the comb so that the bees cannot readily gnaw through the comb to reach the new queen. The new queen is released inside of the cage without any bees other than those which are emerging. A few days later the cage is removed. In the interval, the queen will have been accepted by the emerging bees inside the cage and subsequently by the bees of the colony.

A method of requeening, devised by Charles Mraz, of Vermont, depends on the use of an acid board. This method works successfully with queenless colonies and with those having very poor queens. The acid board is placed over the colony to be requeened and left until almost all of the bees are driven from the hive. The colony then is given two or three combs of emerging brood. The new queen is introduced by removing the cover over the open end of her cage, holding the thumb over the hole while the cage is quickly placed face up on the bottom board. The hive is closed before the queen has a chance to leave the cage. The hive entrance may be partially closed with grass to delay the return of the disorganized bees. By the time they finally work their way into the hive,

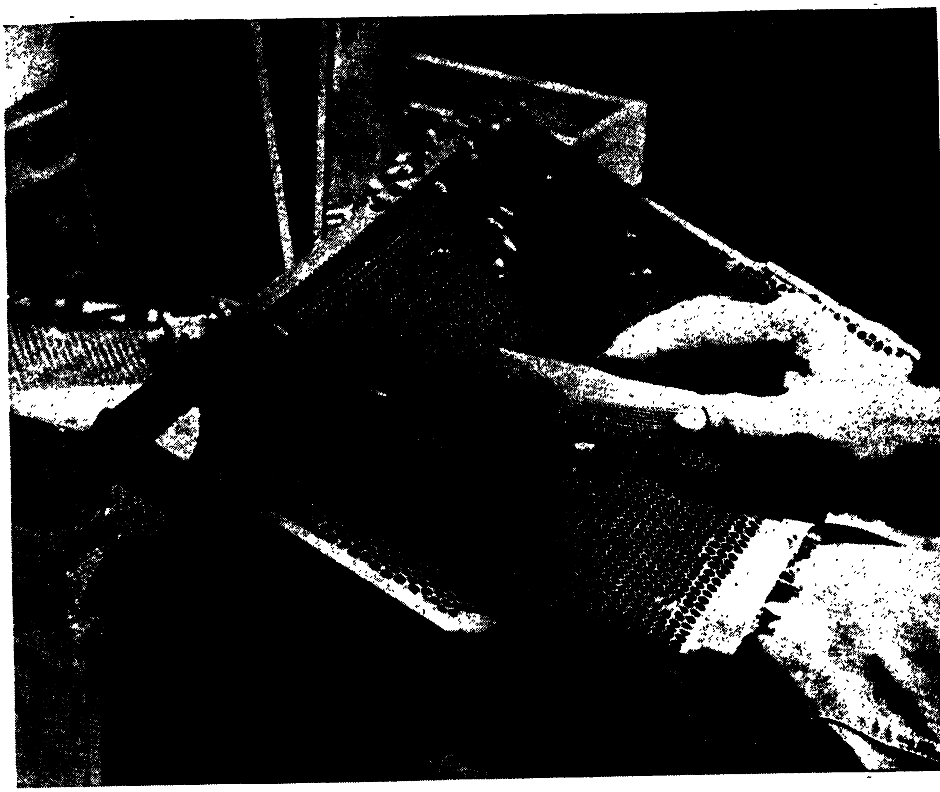


FIGURE 128. The operator is demonstrating the method of placing the "push-in" cage over the queen, before pushing it into the comb. It is recommended that the cage be placed over an area of emerging brood.

the new queen usually is surrounded by young bees and acceptance is good.

Requeening is often successful by a method devised by Howard Shipton, of Iowa. He chooses a cool day in late fall or early winter when only a few bees are flying, when there is no robbing, and the colony is broodless. Often the bees are partially clustered. The old queen usually is found in the center combs among the clustered bees. The old queen is removed and the new queen in her cage is placed well in the center of the cluster between two combs. The paper cover over the candy hole is removed and the cage suspended with the candy end up. As neither queen is laying, the introduction is fairly certain because there is a perfect balance.

This plan of requeening is advisable when colonies are normal and in good condition for winter, but the queens are not thought to be suitable for early spring brood rearing or to be of a desirable strain and, therefore, should be replaced. The plan should not be used with weak colonies having poor queens. Such colonies are often lost in winter, resulting in the loss of the new queen.

### How to Use Two Queens

It is not uncommon in nature for a colony to have two queens. If both queens are laying before the honeyflow, it may account for the extra-large population of a colony and the harvesting of more than the average amount of surplus honey. A number of attempts have been made to use two queens in colony management in order to take advantage of the maximum field force obtained.

Farrar[6] is perhaps the most ardent advocate of the two-queen system of management for honey production. Strong colonies are selected early in the season and divisions are made from them, as soon as available pollen will permit uninterrupted brood rearing for the purpose of introducing a second queen. The old queen is confined by means of an excluder to the lower brood chamber containing a reserve of honey and pollen and half the brood. Two supers of drawn combs are added above the excluder, an inner cover with the escape hole covered with a screen is placed above the supers, and a hive body containing the rest of the brood is placed on top to form an upper brood nest. The upper brood nest should contain combs of emerging brood, plenty of pollen and honey, and over half of the original population. An auger hole in the upper hive provides an entrance. Some of the bees will go back to the lower hive but there will be enough left to maintain a satisfactory population above. A young queen is introduced in the upper hive body, preferably a laying queen from a nucleus.

As soon as the queen in the top hive body has a well-established brood nest, the screened inner cover may be removed, and the bees in both brood nests should be sprayed with sugar sirup. As populations increase, it is necessary to provide more room for brood. Super room is given immediately above the brood nest of either queen as needed, although the lower hive tends to supply bees to the upper one where honey storage is dominant.

The colonies should be united back to a single-queen condition about 4 weeks before the end of the flow. It is not necessary to locate the queens; just set one colony on top of the other and put the supers on top, one queen being disposed of by the bees. In the fall, it may be necessary to provide these colonies with three stories to insure an abundance of honey and pollen for wintering.

Dunham[7] recommends a modified two-queen system which involves the use of two queens during spring and before the honeyflow, and the reduction to a single-queen system at the beginning of the honeyflow.

A modification of the two-queen system which often works is accomplished by wintering the colony in two hive bodies. These are reversed in early spring so that the queen establishes brood in both bodies. Dur-

[6]Farrar, C. L. 1946. Two-queen colony management. *U.S.D.A. Circ.* **E-693.**

[7]Dunham, W. E. 1943. The modified two-queen system. *Amer. Bee Jour.* **83**(5):192–194.

ing fruit bloom, or 6 to 8 weeks before the main honeyflow, the two bodies are set apart, one behind the other, and a queen is introduced to the queenless half. The two colonies are left until the beginning of the main honeyflow, supers often being added to both. When the flow has started, the colony with the new queen is set on the colony containing the old queen and the supers of both are placed on top.

There are many modifications of two-queen management, but it should be remembered that if the management materially increases the costs they must be weighed against the crop obtained. In general, any new procedure should be aimed at reduction rather than increase in costs. Thus, the increased crop obtained under a two-queen system should more than offset the cost of the additional management to be profitable.

## The Swarm

Swarming is an instinctive act stimulated by environment and usually occurs when the colony is crowded with a large number of bees and when the brood nest is so congested with stores and brood that little room is left for further expansion. Demuth[8] stated that the one factor always present in swarming is a congestion in the brood nest, not in the hive itself but in the area occupied by the bees.

The tendency to swarm is usually greatest when bees increase their brood rearing most rapidly in the period before the flow. A colony that has passed its peak of maximum brood rearing some time before the start of the main honeyflow may arrive at the flow in an unbalanced condition. If a colony succeeds in reaching the steady daily intake of a major honeyflow with a well-balanced population, as is the case with colonies that reach maximum strength in the beginning of the honeyflow, the bees usually will concentrate on nectar gathering and show no indication of swarming.

Colonies with older queens, whose egg-laying powers are being depleted, swarm more readily than those having young queens. The failing of a queen will be most obvious at the time when her egg-laying capacity is taxed to the utmost. Her failing will not be so evident in early spring, but as the colony approaches the honeyflow the old queen is not able to do the work required of her. Daily the old queen lays fewer eggs, her laying is less systematic, and the bees become eager to replace her with a young and more efficient queen. Then the bees raise queen cells for the purpose of superseding the old queen (Fig. 134).

Inasmuch as supersedure is most apt to occur at the height of the prosperous period just before or at the beginning of the honeyflow, the colony will dovetail swarming with supersedure. More swarms are the direct result of supersedure than of any other factor. Usually, supersedure

---

[8]Demuth, George S. 1921. Swarm control. *U.S.D.A. Farmers' Bull.* **1198.**

swarms issue with one or more virgin queens, the old queen remaining with the parent colony to be replaced in turn with a new queen. When these swarms are caught and hived, they frequently abscond, flying out and moving to a place of their own choice.

While swarms usually issue in spring previous to the main honeyflow, they may issue during the honeyflow period whenever the hive is crowded. Some colonies reach large proportions and do not swarm; others swarm without any congestion being apparent. The swarming period in warm latitudes may last several months. Whenever there are two distinct honeyflows, there may be two swarming periods. If weather is inclement or if blossoms yield an insufficient supply of nectar, bees are not so apt to swarm.

When the cells built in the hive in preparation for swarming are reaching maturity and when there are few field bees leaving a strong colony on a clear, warm day when other colonies are busily at work, you may look for a swarm unless conditions change rapidly. The usual time for a swarm to issue (Fig. 129) is from 10 o'clock in the morning until 2 o'clock in the afternoon, the majority of swarms issuing when the sun is within an hour of the meridian. However, in sultry weather a swarm will leave the hive as early as 7 o'clock in the morning, and occasionally a swarm ventures out as late as 5 o'clock in the afternoon, but the queen-mother seldom is guilty of such indiscretion.

When swarming is not the result of supersedure and the swarm issues with the old queen it is referred to as a "prime swarm." The issuing swarm contains a varying but relatively large proportion of the older bees

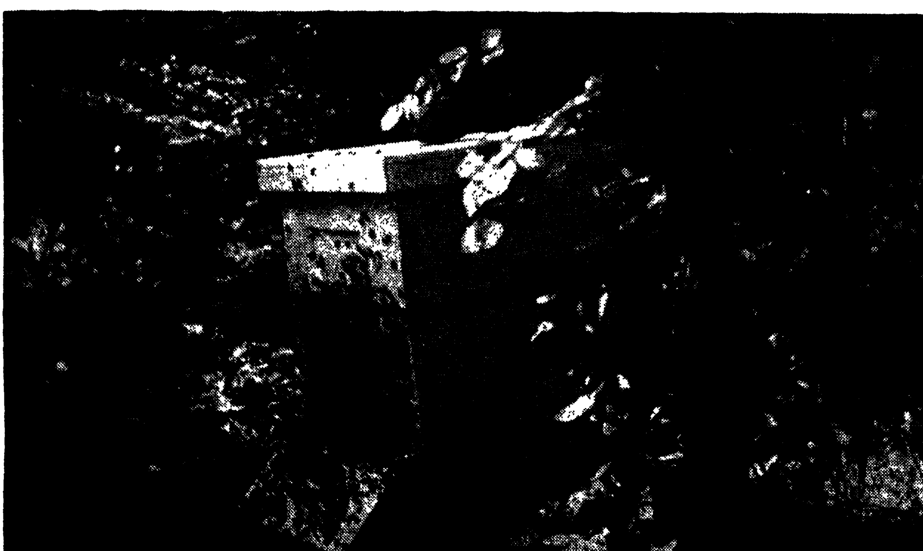


FIGURE 129. A swarm starting to issue—one of the most thrilling sights within the whole compass of rural economy.

FIGURE 130. A swarm of bees about to be hived in a clean cool hive. Later it will be united with its parent colony. This nice swarm obliged the beekeeper by alighting on a near-by low limb of a tree. And the beekeeper arrived in time to hive it before it chose a home of its own.

so that the colony is left with few old bees, a large number of young bees, the brood, and several queen cells ready for the virgins to emerge.

Often, the old queen does not leave the hive until most of the bees of the swarm are in the air. Sometimes she is still so heavy with eggs that she is incapable of rising in the air. The bees will then look for her and, if they fail to find her, they will break cluster and return to the parent colony. If they find the queen on the ground, they will cluster with her and will not return to the hive unless she returns.

When the queen is in condition to fly, she sometimes alights first and the bees then settle and cluster about her. At times, the bees form a cluster and the queen then joins it, but the bees at no time will stay long in a cluster unless the queen is with them.

In very populous colonies, about a week after the prime swarm leaves, more bees may swarm out with virgin queens, apparently when the virgins take their mating flights. There may be several virgins in each of these swarms and this swarming may continue until the population of the colony is reduced to a low point. Anywhere from one to several new colonies may be established by this process.

## How to Catch a Swarm

If the swarm clusters on a low shrub or limb, it can be obtained without difficulty. However, the swarm may alight on a fence post, the wall of a house, a woven-wire fence, or some other place from which it is more difficult to remove. Usually, the quickest way to secure them is to set a nucleus box or hive with combs underneath the swarm (Fig. 130), brushing off all the bees in front of the entrance. The bees should be smoked vigorously to drive them into the entrance, making certain that the queen goes in with the bees. When the bees are all in, the nucleus or hive is taken at once to the spot where it is to be located permanently. If a nucleus box is used, the bees may be transferred to a hive whenever the operator desires.

Too often the swarm prefers to cluster in a tall tree out of easy reach. If the swarm can be reached with a stout pole, a light box is fastened to the end of the pole and then placed in position underneath the swarm. The limb on which the bees have clustered is shaken to dislodge them. A rope thrown over the limb close to the swarm and given a quick pull will do the trick at times.

A nucleus box with combs also may be raised up underneath the swarm and tied in place until the bees find their way onto the combs. This is accomplished by throwing a rope with a weight attached to its end over the limb, and then raising the nucleus box to a proper position. Frequently, by climbing the tree, sawing off the limb on which the swarm is clustered, and carefully lowering it, the bees can be easily hived.

A laying queen in a cage can be fastened on a comb at the end of a pole and the comb pushed up among the bees of the swarm. Usually, the bees

will cover the comb and then it can be lowered to the ground and placed in a hive, allowing the bees to keep the caged queen until it is certain that their own queen is present and laying. If they do not have a queen, the caged queen may later be released among the bees.

A cloth sack with its mouth sewed to a wire loop fastened to the end of a pole may be used for securing high swarms. The sack is lifted up until it surrounds the swarm, the limb jarred, and the mouth of the sack quickly turned to close the opening. After being lowered to the ground, the swarm is carried in the sack to where it is to be hived.

If a swarm issues when the beekeeper is present, he may be able to spray the swarm with water from a hose so that the bees will fly with difficulty. They usually will then cluster in a low place. Inasmuch as swarming bees cluster when some of their numbers begin to settle, dark or black objects, which the bees seem to mistake for the swarm, placed conveniently about the apiary may attract their attention. An old black hat or a piece of dark cloth fastened at the end of a stick or pole will do. These devices are not infallible but often are effective in attracting the bees to cluster on them.

Some beekeepers use decoy hives to attract swarms. These are old hives or boxes containing combs and placed in the crotches of trees. The scouts sent out by the swarms to locate new homes may choose these places and the swarms later will enter them of their own accord.

## How to Hive a Swarm

Because the swarm divides the population of a colony, resulting in a reduction in the field force and consequently the amount of honey the colony might have gathered, it is obvious that the swarm and its parent colony should be put back together to make the best use of the bees. Only if the swarm occurs considerably in advance of the main honeyflow will it or the parent colony build to strength and secure a satisfactory surplus crop.

One method of returning the swarm to the parent colony is to hive the swarm in a new hive on the old stand. If there were supers on the parent colony, they are placed on the swarm in the new hive. A queen excluder or an inner cover with the center hole open is put on top of the supers and, after having destroyed all queen cells, the parent colony is set at the top and left there until all of the brood has emerged. The population is thus brought back together and further swarming is unlikely, particularly if the old queen, which may have issued with the swarm, is replaced with a new queen at the earliest convenient time.

A variation of this method is to set the parent colony close beside the swarm which has been hived on the old stand. The entrance of the parent colony should be at a right angle to its former position. The field bees that leave the parent colony then will enter the hive of the swarm because it is on the old stand. All but one or two of the best queen cells,

preferably those from which the virgin queens are not due to emerge for a few days, are removed from the parent colony. One of the virgins will mate and provide a queen for the parent colony. After about 10 days, move the parent colony to the other side of the swarm in a similar position. Thus the parent colony will steadily lose its field bees to the swarm. After its queen is mated and laying, the colony may be set in a new location as an increase in the number of colonies in the apiary. Inasmuch as the majority of the field force will have joined the swarm in this process, not much of the crop will be lost.

If a swarm is hived on a full set of drawn combs, the bees may soon fill the cells with nectar, restricting the egg laying of the queen. If the new swarm, however, is given supers in which the bees were working prior to swarming, a full set of combs may be used in the brood nest with little trouble. On the other hand, because a newly hived swarm will draw foundation readily when there is a good quantity of incoming nectar stimulating the secretion of beeswax, frames of foundation can be given to the swarm. The queen is able to use the newly constructed cells as fast as they become available. Space is thereby provided for her in a more satisfactory way than when all of the combs given to the swarm are drawn combs.

## Swarm Prevention and Control

Because swarming is an instinctive habit which follows a natural sequence of conditions, the beekeeper must follow this sequence carefully to make certain that each colony is led away, step by step, from that culmination of circumstances which results in a swarm.

Populous colonies with the best queens (Fig. 131) are frequently unable to stand the congestion of the brood nest. This congestion throws the colony out of balance in population and queen cells are started in preparation for swarming. Therefore, the brood nest should be kept as free as possible at all times from any condition which will contribute to congestion. There should be plenty of worker combs containing empty cells for egg laying and with a minimum of honey and pollen in them.

The addition of more empty combs may be necessary at the sides of those occupied with brood so that the queen may use them, or room may be provided for the empty combs by removing those occupied with honey and pollen. Thus the queen is induced to expand her brood area to the sides. Additional bodies of combs may be placed on top into which the queen may go, expanding her brood area in an upward direction. Supers also can be added for the storage of nectar and honey so that it will not be crowded into the area occupied by the brood. This is the basic idea of a free brood nest by the provision of areas for definite use.

Any management that adds to the comfort of the colony will aid materially in the prevention of swarming. Colonies may be shaded, they may be given ventilation (Fig. 132), and adequate watering places should

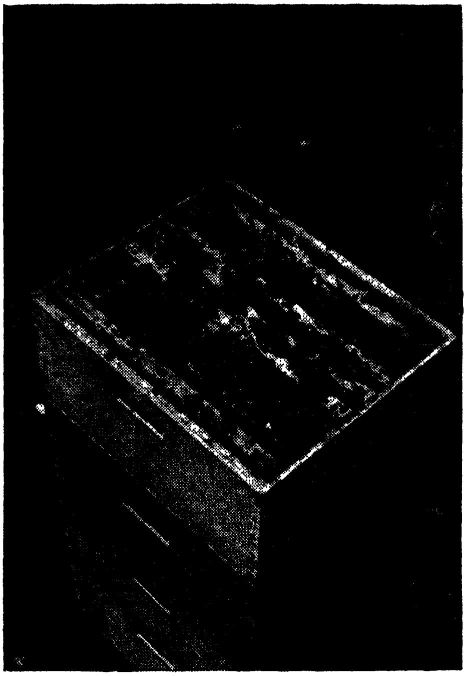


FIGURE 131. Big colonies like this one will swarm "at the drop of a hat." (*Photo by Wm. L. Coggshall*)

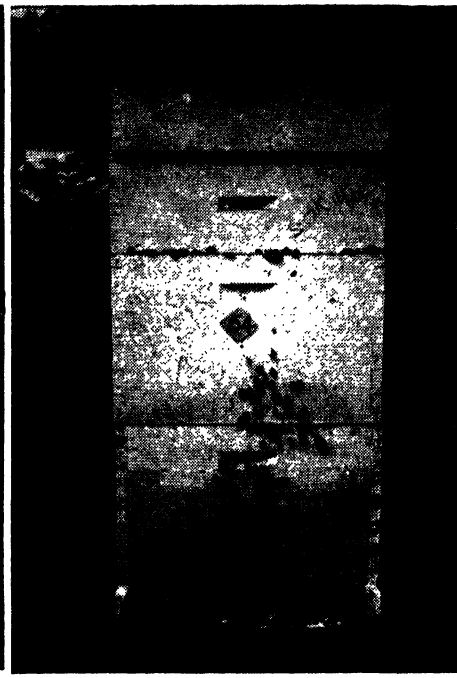


FIGURE 132. A big colony made comfortable by raising the entrance, and staggering the top super for better ventilation.

be at hand inasmuch as the colony is kept cool in very warm weather through evaporation of water by the bees.

During the period when colonies are most likely to attempt swarming, an examination of a few selected at random throughout the yard, particularly the strong ones, will give the operator an idea of existing conditions. The brood bodies can be separated or raised from the bottom boards and the lower edges and sides of the combs examined to see if queen cells have been started, A thorough examination of the individual combs of a few of the strongest colonies at the same time will increase the value of the superficial examination already made. If there is little evidence of swarm preparation, further attention will not be needed.

Swarm cells are numerous and are usually constructed along the lower edges of the comb (Fig. 133); the bees start one or two each day over a period of a week or more so that the cells are not of the same age. Supersedure cells, on the other hand, are usually built on the surface of the combs (Fig. 134) and result from the heavy feeding of larvae with royal jelly until they have been floated out on their food to the mouth of the worker cells and queen cells then erected about them. Supersedure cells are usually about the same age and few in number. Swarm cells provide many young queens for the full expression of swarming; supersedure

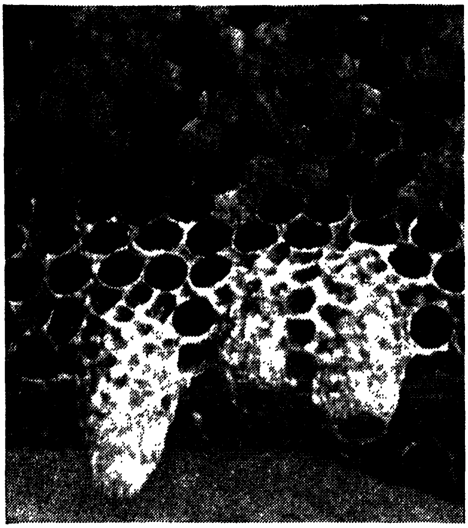


FIGURE 133. Swarm cells in their usual place along the bottom of the comb. Usually they are whiter than supersedure cells.

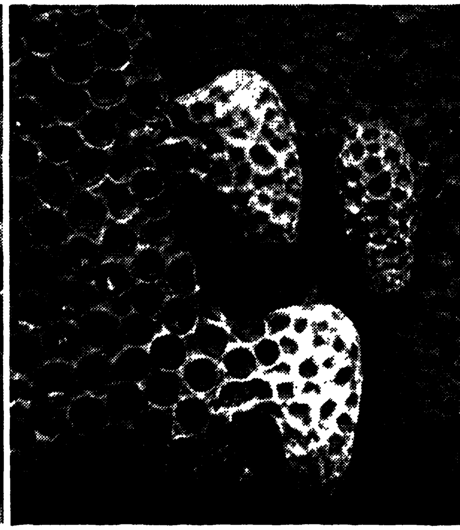


FIGURE 134. Supersedure cells are few in number, usually of about the same age, and constructed on the face of the comb.

cells make certain that there will be a queen on hand to mother the colony in place of an undesirable queen. For additional information on the two types of queen cells, see Chapter III, "The Honey-Bee Colony—Life History."

Special practices are often used to control swarming; among the well-known methods is the so-called Demaree plan of swarm control. This method may be used when individual colonies have swarm cells, or it may be applied to all the colonies in the apiary at one time when it is apparent that most of them will develop cells.

The brood of the colony is examined and all queen cells are destroyed. The hive is then removed from its bottom board and a body containing one comb of unsealed brood, eggs, and the queen is put in its place with the remaining space filled with empty combs. A queen excluder is placed on top of this body. Supers are put above the excluder and the remainder of the brood and the bees are placed at the very top. The colony still has all of its brood, and the queen is in the lower body with a free brood nest.

In 10 days, examine the brood combs in the top hive body and remove all queen cells that may have been built in the interval. In 21 days, all of the brood will have emerged in the upper body and it will be used for honey storage, while bees will be beginning to emerge from new brood in the lower body, so that a continuous succession of young bees is maintained. Except in unusual seasons, it is seldom necessary to use the Demaree plan more than once.

Should a swarm be likely to result from supersedure, swarming may be prevented by removing the old queen and any queen cells which may

have been started. Wait 10 days and again remove any cells that have been built in the interval. There will then be no brood left of an age suitable for queen cells. A young laying queen may now be introduced and it is seldom that the colony will attempt to swarm again that season. This method is particularly valuable in the production of comb honey.

A similar condition may be brought about by forced supersedure. When colonies are in a two-story brood nest, a queen excluder is inserted between them 4 days before giving a new queen or a ripe queen cell to the queenless portion. It is not necessary to find the queen because, after the 4-day interval, the part with eggs and young larvae obviously is the one that contains the queen. This part is set aside and the queenless part left on the old stand and given a new queen or a ripe queen cell. A day later, a super of combs is placed next on top and an inner cover with its center hole covered with queen-excluder zinc is placed above the super. Finally, the brood body with the old queen is placed at the very top. The old queen is permitted to continue her laying for at least 2 weeks after the young queen below has started to lay, and then the old queen is killed and the excluder removed.

During a period when swarming is apt to occur, if bees are confined at intervals to their hives by rain or inclement weather so that they have access to the fields and then are compelled to remain in the hive in successive periods, this intermittency may stimulate swarming. To control its effect, a thin sugar sirup may be fed to the colonies. This feeding has the effect of an uninterrupted flow, restoring the balance of the colony and tending to avoid swarming. If the colonies are given supers sticky with honey the same effect may be produced.

The exchange of strong colonies with weak ones in the apiary, so that weak colonies are strengthened by the addition of the field force of stronger ones, and strong colonies lose strength to the weak ones, is a swarm-preventive measure that works satisfactorily and does not involve the exchange of combs or the use of additional equipment. In outyards, where the attention required by most swarm-control methods is difficult, a variation of the exchange plan, called relocation, has been developed.[9]

It is the practice in the Dadant apiaries to diagram the colonies as shown in the example (Fig. 135). The relocation of the colonies is indicated by arrows. Colonies are examined for queen cells and any found are destroyed. Such colonies are placed either in the location of weak colonies or in new locations at the front or back of the yard, or at the end of a row. By this exchange, the colony which had the swarm cells loses much of its population; this is equivalent to the normal condition of a colony which has swarmed because there will be mostly young bees with the queen in the hive. The field bees of colonies that have been placed in spots previously unoccupied by colonies will return to their old locations,

[9] Cale, G. H. 1944. Relocation as a means of swarm control. *Amer. Bee Jour.* **84**(5):155–156.

entering neighboring colonies and increasing their field forces. While the relocated colonies may continue to develop queen cells to carry out supersedure, they will not swarm.

Colonies whose strengths are too much alike should not be exchanged. Those in which virgin queens have already emerged cannot be helped by the exchange. When the virgin queen has emerged the swarm is as good as in the air.

Divides may be made of colonies in which virgins have emerged or from those containing swarm cells from which they will emerge within a few days. These colonies should be taken to another location at least 2 miles away and the brood and bees divided into any desired number of parts, giving each part a new queen or allowing a virgin to mate. This removes the colonies from the production of surplus honey and uses them for increase.

Various devices have been used to control swarming, such as placing a queen-and-drone trap over the entrance to screen out the drones in the belief than an excess of drones is the direct cause of swarming. The same device is used to keep laying queens from going with the swarm when it issues. However, when a queen has reduced her egg laying previous to the issuance of the swarm, she often is able to make her way through such

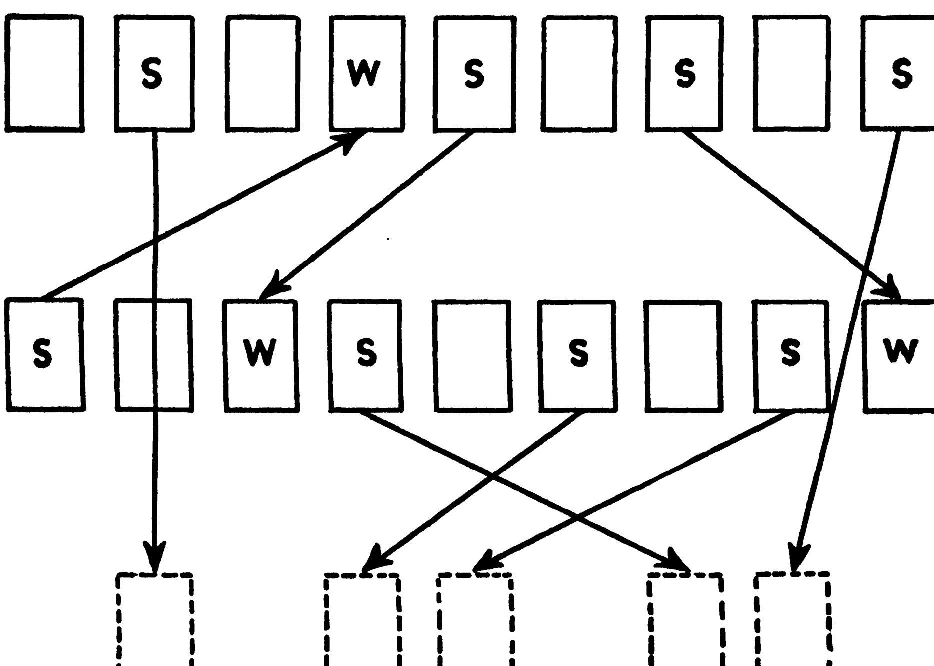



FIGURE 135. Diagram of "relocation" of colonies as a method of swarm control. Strong colonies are indicated by the letter "S," weak ones by the letter "W," and arrows indicate possible relocation of colonies.

traps. If the swarm is accompanied by a virgin queen, she can leave readily in spite of the device which is expected to prevent her flight. Such devices, therefore, are of little value.

Beekeepers sometimes clip the wings of queens to prevent them from flying away with the swarm; clipping will accomplish this. But, if the swarm has failed in an attempt to leave with the old queen, the bees will return to their hive and wait until virgins have emerged, and then issue with one or more virgin queens. So, clipping is, at best, only a temporary deferment of swarming. It does give the beekeeper time to do something about it provided he is able to determine the hive from which the swarm has issued and returned. However, clipping does not prevent the swarm occurring.

## How to Move Bees

If bees are to be moved only a short distance, such as across the bee yard, to a different position in the apiary or across a city lot, a simple way to accomplish the move is to change the position of the colony a little each day so gradually that the bees will not be confused by the new position of the entrance. A satisfactory distance may be judged by the tendency of the bees to drift to other colonies after each step in the move is accomplished. If there are no other colonies close to the one that is being moved, it may be moved farther at each move. Colonies may also be moved farther to the front or to the back than they can be moved sideways. If they find their own entrance readily, the distance is safe.

It is possible to accomplish a short move quickly by carrying the colony to the desired location late in the day after the bees have quit flying. A board should be leaned against the front of the hive so that the bees will be confused by this obstruction the next day and will mark the new place. A hive containing a set of combs can be placed on the old location to catch any bees that may go back to their former location. In the evening, when all of the field bees have returned, set the body in which the bees have been caught above a newspaper on top of the original colony in its new location, as in uniting.

If bees are to be moved a considerable distance, they should be moved at least 2 or 3 miles beyond the flight range of their former place. When this is done few bees will return to the old spot. It is preferable also to do the moving when the field bees are all in the hive, either late in the day or very early in the morning.

Make sure that any small cracks or openings between the hive parts are closed by filling them with paper, rags, or similar materials so that the bees will not find their way out during transit. The bottom boards and hive parts must be fastened securely. Hive staples are made for the special purpose of fastening the hive parts together. When using them, be sure that the two staples on each side used to fasten two parts, such as the hive

and the bottom board, are slanted in the opposite directions. Otherwise, they may shift position when raising and handling the colonies. In hot weather, the hives should be provided with a top-moving screen (Fig. 136) to provide a clustering space and air for the bees. It also is a decided advantage to use entrance screens (Fig. 137).

When colonies are loaded on trucks (Fig. 138) or other vehicles, each layer of hives should be separated by wood strips to provide a space between for the free movement of air. Properly prepared colonies can be moved in the hottest weather. The truck should be kept moving, but if stops are necessary it should not be parked in the sun. It is a good idea to carry extra gasoline so stops do not have to be made at filling stations. There are always some bees riding along on the outside of the hives; they will fly when a stop is made and often cause trouble when left behind.

If the frames in the hives are not self-spacing, they must be made secure by nailing light strips of wood across the top bars to prevent the combs from moving together and crushing the bees. Self-spacing frames in hives that are not full should be crowded tightly to one side and the ends of the top bar of the outside frame nailed securely. In lifting and carrying a hive, support the back of the hive against the body; do not carry the hive sideways or the frames may swing together and kill the bees.

It is ideal to arrive at the new location so that the entrances may be opened and the screens removed just before dark. In any case, the truck

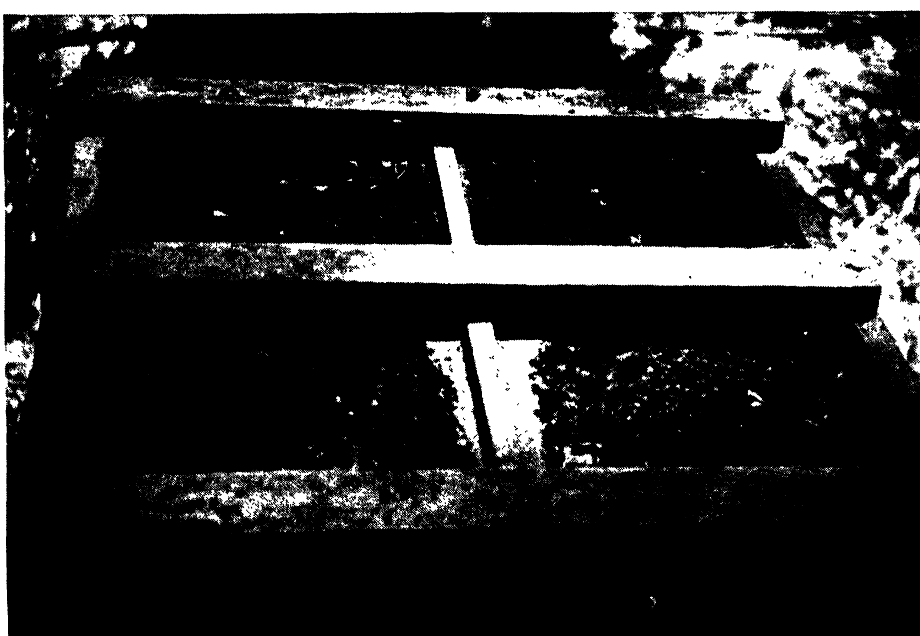


FIGURE 136. The top moving screen provides additional ventilation and clustering space when moving colonies of bees.

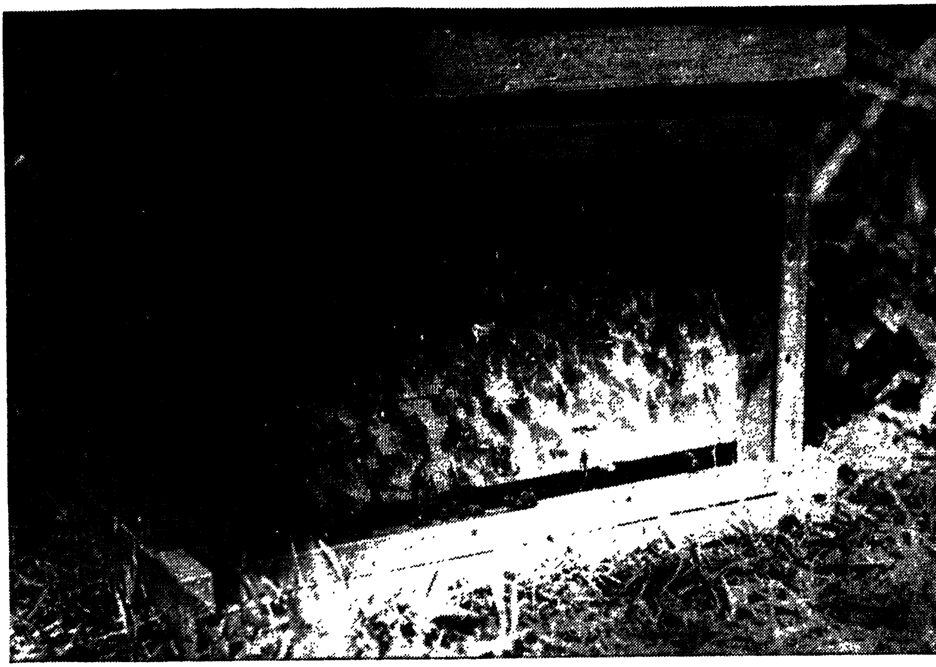


FIGURE 137. Entrance screens should be used in hot weather as they provide more clustering space and ventilation than when only the top moving screen is used.

should be stopped in a shady place, if possible, and all of the colonies should be unloaded and located before the screens are removed. By the time all are unloaded, the bees in the first colonies removed will have settled down considerably and entrances can be opened and screens removed. On a bright, hot day, it is helpful to spray the bees with water to prevent rapid flight and drifting.

In the cool weather of early spring or late fall when bees are not flying, or after they have ceased flight for the day, colonies can be moved without any special preparation. The bees make little attempt to come out of their hives while the truck is in motion. If the weather is too cool for flight, the colonies may be left on the truck until morning before unloading. Some beekeepers move this way in warm weather but there is danger of loss if it is necessary to stop the truck. Because the bees come out of their entrances on the trip and more or less mingle, there is considerable confusion among the colonies and it almost always results in a severe stinging for the operator.

## The Prevention of Drifting

The drifting of bees from one hive to another because of wind or confusion caused by other circumstances is common. A high wind may buffet bees coming in from the field until they find themselves in the

FIGURE 138. A truck and trailer load of colonies ready for a long journey. (*Photo courtesy Rocke Apiaries*)

wrong hives, even though they make their best effort to return to their own home. Drifting often is most noticeable at the ends of rows in the direction of prevailing winds which force the bees down the row until they come to the last two or three hives and rush in pellmell. These bees are always welcome because they come in laden with nectar, pollen, or water, and they are not robber bees.

If bees that have been wintered in a cellar are removed in spring in the middle of a warm, sunny day, they fly freely in their first flights. Because their sense of direction has not been established, they drift readily from one hive to another, particularly if a wind springs up. This sometimes results in the depletion of the adult bees of some colonies and an increase in those of other colonies. It is best to remove colonies from a cellar toward evening, or when the weather is cool and inclement, so the bees will not fly at once. Entrances should be reduced and a board leaned against the front to cause the bees to orient themselves. If bees are removed when snow is still on the ground, flight may be reduced by putting snow across the entrances of the hives, and flight will be established gradually as the snow melts.

If package bees are installed on a bright, sunny day and are permitted to fly too soon, they will drift in the same manner, causing serious losses in the population of some of them. Greater skill in hiving the packages would have prevented this (see "The Management of Package Bees").

The effects of drifting may be corrected by exchanging the positions of colonies that have become strong with those that have been weakened. This exchange should be made preferably when there is nectar available and bees coming in from the field enter the hives without being molested.

A frequent occurrence is the drifting of young bees in their play flights. Not having thoroughly learned the location of their own hives, they may drift into neighboring hives when affected by wind. The next day this drift may be corrected by changing winds. When disease is present in the apiary, these drifting young bees frequently may spread disease. Obviously, the best way to avoid this trouble is to make frequent examinations and to remove any diseased colonies at once.

The arrangement of colonies close together in straight rows encourages drifting in the apiary. Colonies should be placed 6 to 8 feet apart in the rows with 10 feet or more between the rows. If colonies are arranged in rows, with the hives in every other row placed so they are opposite the middle of the spaces between the hives in the next row, thus staggering the positions of the colonies, it will have a tendency to reduce the amount of drift. In windy and exposed places, a good windbreak will also reduce drifting.

Drones tend to drift about the yard more freely than worker bees and are welcome in almost any hive during summer. It is not infrequent to find drones of both light and dark color in every hive, even though they may originate in colonies where drones of one color predominate.

## How to Unite Bees

The occasion frequently arises when it is necessary to put one or more groups of bees together, one colony with another or one nucleus with another nucleus or with a colony. Weak colonies in fall may not winter well; it is usually best to unite them with other colonies which will be strengthened by the union. Colonies with good queens which require strengthening may be united with small colonies having unsuitable queens, the poor queens being destroyed. This makes the better colony stronger and disposes of the weaker one.

It is frequently considered good practice to unite weak colonies just previous to the main honeyflow. Such colonies should be permitted to grow until that time. Then, any that are unsuitable for the flow can be united with other colonies that thus will be benefited. It should be remembered, however, that weak colonies with exceptionally good queens may grow rapidly into populous colonies.

If uniting is necessary during summer when little nectar is available and robbing is apt to occur, it is advisable to set the colony that is being united above the other colony on top of a single thickness of newspaper with one or two small holes punched in the center. The bees gnaw away the paper and gradually mingle together as time goes on, and so unite peacefully without excitement. After a large portion of the newspaper has been removed by the bees, the remainder may be removed by the beekeeper, and any extra combs resulting from the union can be disposed of as desired. It is not necessary to find either queen unless there is a prefer-

ence for one of them. Then the undesirable queen may be found and disposed of before the colonies are united.

A quick way of uniting is to kill the poorest queen of the two units that are being united, and to place most of the brood of both colonies in one hive with the remaining queen and part of the bees. Then shake all of the remaining bees from both colonies in front of the hive, sprinkling them with sugar sirup and smoking the entrance. Bees returning from the field will enter the hive at once, and there is so much confusion that there is seldom any fighting.

Another quick and easy way is to set the best colony with its queen above an excluder over the lower colony which has been made queenless. The excluder checks rapid mingling of the bees, there is usually little disturbance, and the bees of both hives unite peacefully.

Strange units of bees often cannot be put together without the bees of the two parts fighting. The degree of antagonism between them depends on weather and colony conditions, and there is no rule for uniting that will suit all occasions.

In early spring or in late fall, colonies often may be united by merely placing them together. Whether one is set on top of the other, or whether the combs of each are placed together in a single hive, makes little difference. During a honeyflow when bees are busy in the field, two colonies may be put together by placing one immediately above the other, or they can be placed together in the same hive without special preparation. In the fall, it is often possible to shake the bees off the combs of a colony in front of the hive of another with which they are to be united. When there is no brood and the weather is cool, the bees enter peacefully and mingle together without any fighting.

In uniting bees, one will be reminded that some of the field bees will fly back to the parent stand, while the young bees will stay with the union. However, the loss of some of the field bees is not important because they usually drift into neighboring colonies without hesitation.

## How to Transfer Bees

Sometimes it is necessary to transfer bees from one kind of equipment to another, or to remove them from houses, trees, or other natural lodgings. Many colonies are still housed in log gums, box hives, and various other domiciles in which the combs are crooked or run crosswise. Such colonies should be transferred to modern equipment because they cannot be managed properly and they produce only a small amount of surplus honey.

In buying bees which need to be transferred, the cost of the work should be considered in the purchase price. The combs usually are worth only the value of the wax in them, the bees are worth no more than the price of a package of bees, and often the hive is of little value.

The best time to transfer bees, particularly if it requires exposure of combs that may incite robbing, is in a period of honeyflow. An ideal time is during fruit bloom in spring; the amount of brood and bees in the colony then is relatively small and the work is easier.

Direct transfer is sometimes used in removing bees from trees or houses. If the bees are in a tree, it may be necessary to cut away enough of the wood of the tree to expose the colony (Fig. 139) in order to effect direct transfer. When the bees are in a house, portions of the building may have to be removed to expose the combs. After the combs are exposed, they are removed by cutting them out one at a time with a sharp knife and the bees shaken into the new hive. Portions of combs that are desirable to use, particularly parts containing worker brood, are cut to fit the inside of frames and tied in place in the frame with string, or by other means (Fig. 140). The bees will repair, strengthen their attachments, and use the combs. If they are found to be undesirable combs, they may be placed in a hive body above an inner cover with the center hole open until the brood emerges. They then may be removed and melted into beeswax.

After transferring is completed, the new hive may be left close to their old home until all of the field bees have entered and accepted it as their

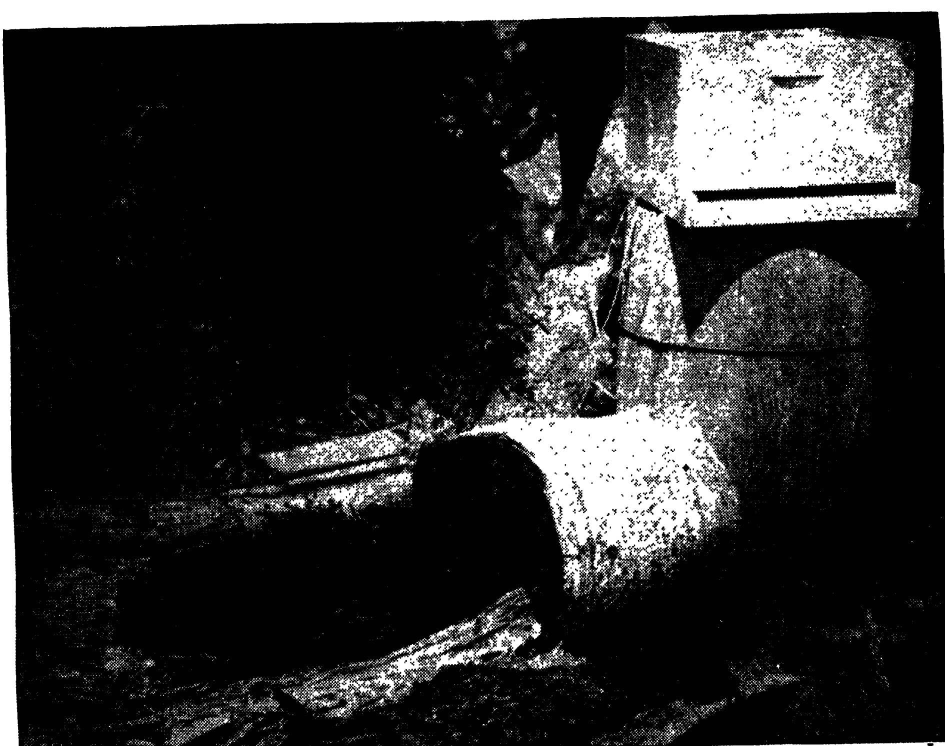


FIGURE 139. A tree colony with the wood cut away to expose the combs is now ready to be transferred to the modern hive.

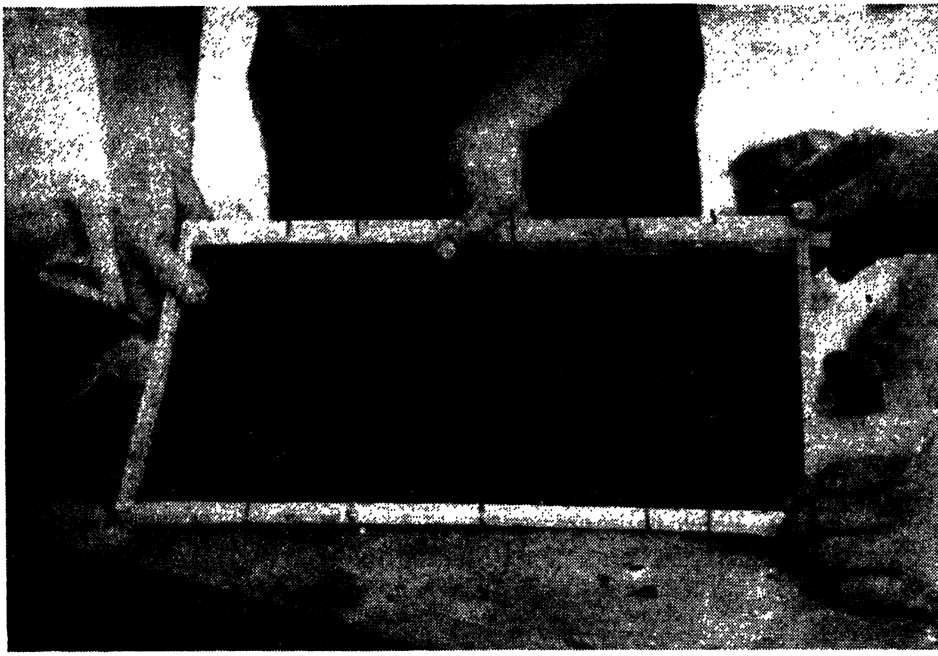


FIGURE 140. The worker comb is cut to fit the inside of the frame and tied temporarily into position with string or other means.

new home. The hive is then closed and moved to a new place 2 or 3 miles from the original location so that the bees will not return to their former home.

If it is not possible to expose the combs of the colony in transferring, the following method may be used. A nucleus is made containing two or three combs of brood and bees and a new queen. The nucleus is placed on a temporary shelf so that its entrance is turned at a right angle to the entrance the bees have been using (Fig. 141). All entrances which they may have been using, except the main entrance, should be closed. A cone of screen wire is then made with the small end of the cone reduced to leave a space sufficient for only one bee to enter or leave the cone at a time. The large end of the cone is fastened to the old entrance so that bees go out through the small end of the cone, but have difficulty in finding their way back through the cone entrance. Gradually, the bees will then join the nucleus. When the population of the old colony has reached a low point, the remaining bees may be killed with a suitable fumigant, the old entrance stopped up, and the bees in the nucleus removed to a new location.

Bees in box hives or containers in which the combs are crooked and crosswise also may be transferred by the cut-and-tie method, but slower and better ways are usually advisable. A good way is to turn the old hive over, remove the bottom board, set a new hive body with frames of foun-

dation or combs over the open bottom of the colony, and close tightly any remaining spaces between the hive bodies so that the bees may come and go only through the entrance of the top hive. Then, with a stick in each hand, drum the bees from the bottom hive into the hive above, rapping continually on the sides of the old hive. This causes the bees and queen to run up into the new hive. The drumming should be continued for some time; if it is possible to smoke into the old hive, this also helps to cause the bees to move upward.

Finally, a queen excluder is slipped under the bottom of the new hive to keep the queen confined to that body. The worker brood in the body below will have emerged within 21 days and in the meantime the colony will have established itself in the new hive. The excluder can then be removed, the bees on the old combs can be shaken in front of the new hive which by then is setting on a bottom board on the ground, and the old equipment and combs can be taken away and disposed of as desired.

Should a prime swarm issue from a colony that needs to be transferred, the swarm is hived in a new location in a modern hive containing a full set of good combs or frames containing comb foundation. The old hive with the bottom board removed is placed over an inner cover with the hole open and above the supers of the new colony. An entrance is not provided for the upper hive and any openings should be closed. When the virgin queens emerge in the upper hive, they will find their way down to

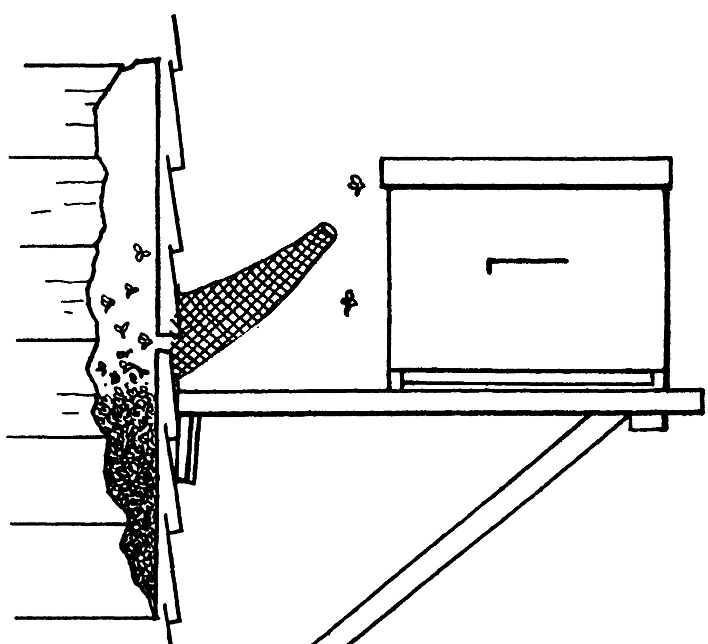


FIGURE 141. Diagram of transferring a colony of bees from a house by means of a screen-wire cone. (*Drawing courtesy J. E. Eckert*)

the lower colony where they will be killed. When all of the brood has emerged from the combs in the upper body, the old combs and equipment can be disposed of as desired.

In transferring from small hives to larger ones when both contain removable combs, such as transferring an 8- or 10-frame Langstroth colony to a Modified Dadant hive, take two or three brood combs with the queen from the small hive and put them directly into the large hive, filling the rest of the space with full-sized combs or frames containing comb foundation, of the Modified Dadant size. A queen excluder is put over the top of the large hive, the small hive is set on top, and the open spaces at the sides are closed. The queen below will gradually work over to the larger frames, and the smaller frames can then be returned to the small hive body above the excluder. When all of the brood has emerged, the small hive can be removed, used as a super, or disposed of in some manner.

## Supplying Ventilation

It is often necessary to ventilate the hive in order to cool it on warm days so the colony will be more comfortable, and to aid in the evaporation of nectar. Ventilation is accomplished by bees fanning their wings at the entrance and within the hive on the bottom board, the extent of fanning being determined by the need for ventilation (see Chapter IV, "Activities of Honey Bees").

If the entrance to the hive in warm weather is small, bees may not be able to set up sufficient currents of air for ventilation. Should the entrance become clogged from one cause or another, it is not uncommon for the combs of the colony to melt down and for the bees to perish. This often occurs when hives are located where it becomes extremely hot in summer and there is insufficient ventilation throughout the colony. The top combs of honey melt first, the melted wax and honey finally running out of the entrance and partially or completely suffocating the entire colony. It is not unusual for bees under such circumstances to stop their field work and cluster on the outside of the hive until conditions improve.

The beekeeper can help ventilation by keeping the bees in partially shaded places, using shade boards on top of the colonies, cutting away weeds and brush in the apiary to allow circulation of air, and especially by providing a large and deep entrance to the hive in warm weather.

It sometimes is advisable to give additional ventilation by offsetting the top cover. Some stagger the supers slightly forward and backward (Fig. 132), although this is not advisable when producing comb honey. Frequently, it is good practice to raise the front of the hive body at the bottom board with small blocks, or the hive can be raised in this manner at all four corners. Later in the season, special ventilation spaces should be closed because of the possibility of robbing and because of the approach of cool fall weather.

## Securing Good Combs

Before the advent of comb foundation, combs in the hives were built entirely from beeswax secreted by the bees as needed and according to their own designs. The resulting combs were often joined together and of various sizes and shapes.

When comb foundation was developed, the beekeeper was able to use full sheets of it in each frame and to obtain combs vastly superior to those he had been able to obtain previously. In late years, reinforced comb foundation, in which both vertical and horizontal wires are used, enables the beekeeper to get combs that are nearly perfect. However, unless comb foundation is given to the bees when they are naturally secreting beeswax and building combs, they will not build good combs, even from the finest foundation (see Chapter V, entitled, "The Honeycomb").

The ideal time to secure good combs is during a honeyflow, and the best combs are obtained from frames of foundation placed in hive bodies or supers immediately above the brood nest. Then the bees will build combs out fully, from one end bar to the other and from top bar to bottom bar (Fig. 142). They will be composed largely of worker-size cells and are the very best that can be obtained for brood rearing and for honey storage. If they are left with the colony and used for honey storage during the honeyflow, they can be extracted and later used in the brood nest when they are needed. It is a good practice to draw new combs in this way each year for use the following season. Poor combs should be removed from the colony at every opportunity until all the combs of the colony are as nearly perfect as can be obtained.

The best way to remove combs that are no longer suitable (Figs. 143, 144) is to take them from the brood nest of the colony during the honey-

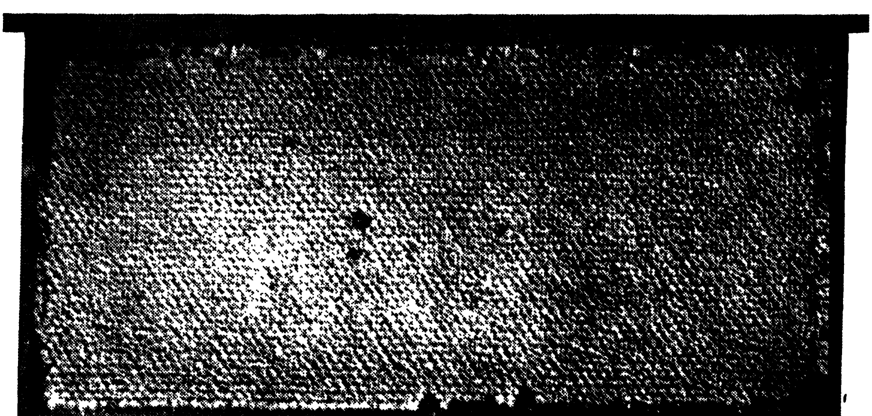


FIGURE 142. A good honeycomb drawn from a full sheet of comb foundation in a frame placed above the brood nest in a good honeyflow—good beekeeping practice.

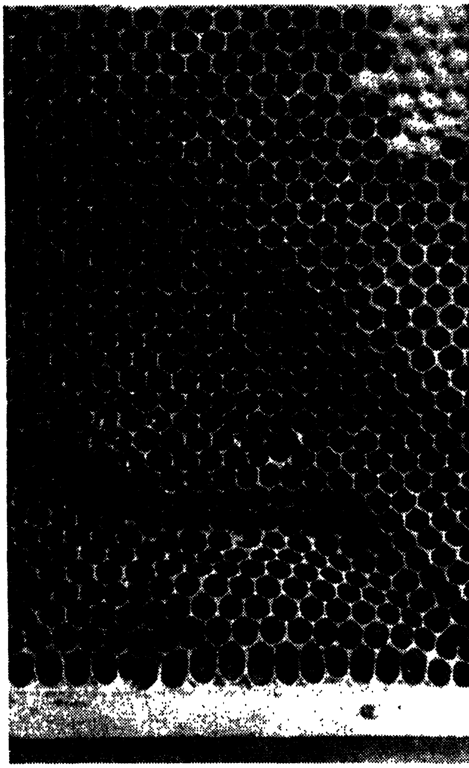


FIGURE 143. This comb has sagged causing a bulge at the bottom and contains a few drone cells.

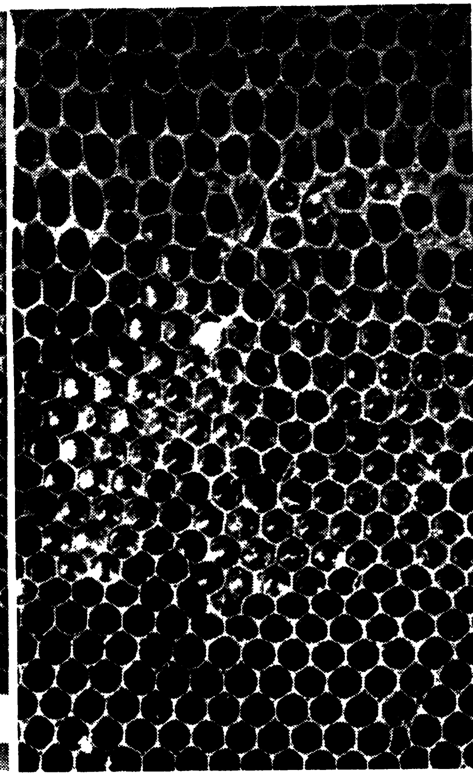


FIGURE 144. The sagging at the top of this comb has resulted in many stretched cells used for rearing drones.

flow and to replace them with good drawn combs. In a good flow, it is possible to remove two or three at a time from a strong colony and to replace them with frames containing full sheets of comb foundation, although this is not as desirable as replacing them with fully drawn combs. The poor combs may then be placed in hive bodies and set on top of any colonies over inner covers with the center hole open. The brood will emerge and the bees will not store honey in the combs, but even will remove the honey from these combs, storing it below in the supers. If the undesirable combs contain only honey, they can be extracted and later melted into beeswax.

## The Care of Equipment

There seldom is time to concentrate on the care of equipment when it is necessary to think about colony development in spring, harvesting the crop, and preparation for winter in the fall. Nevertheless, equipment represents a greater investment than the bees. Inasmuch as it is possible to replace bees at relatively less expense than it is to replace equipment,

it is good sense to keep equipment in first-class condition—repaired, painted, and damaged or worn-out parts replaced. This task can be done best in the off season in a suitable workplace where it is comfortable to work.

Supers and hive bodies should be renailed if they are not firm. Inasmuch as they spend much more time out of doors than inside, a good coat of paint will help to preserve them and to prolong their life. Cracks in equipment should be filled with plastic wood, and holes should be plugged or covered. Bottom boards deteriorate faster than other equipment especially when set on the ground. Even when hive stands are used, bottom boards are subject to more moisture and insect damage than hive bodies, supers, or covers. They will last longer if painted with a wood preservative or dipped in creosote and dried in the sun before they are used. This should be repeated every 3 or 4 years.

Good hive stands can be made of corrugated metal, wood, or concrete. Often four bricks at the corners of the bottom boards are used, or two logs or wooden runners are placed underneath. Sometimes hives are set on 2- by 4-inch stringers running lengthwise of a short row, the stringers fastened to posts set in the ground.

A portable sprayer is useful in painting equipment. Supers can be stacked together and painted quickly. The portable sprayer also can be taken into the yard and hives painted when the bees are not flying freely and conditions are satisfactory for the paint to dry.

Winter is also a good time to repair honey house equipment—to clean, wash, and paint the walls and floors, and to make all ready for the coming season. It is a good time to make changes and add conveniences that will improve the efficiency of honey production.

## Natural Factors That Influence Management

Weather has a marked influence on management. For example, bees sometimes are unable to obtain nectar abundantly immediately after a rain. A cold rain will often cause the secretion of nectar to be reduced so that an abundant flow is not re-established for several days. The intermittent occurrence of rain and sunshine in the early part of the honeyflow, alternately preventing bees from flying and then releasing them to the fields, affects swarming. This is probably why some years are known as bad-swarming years and others are noted for the occurrence of only an occasional swarm.

The beekeeper usually suits his work to the weather. He learns what he can and cannot do in the weather at hand. When it is cold, bees may be moved readily without closing the entrances and without provision for ventilation. They also may be united more readily. When bees are apt to rob, much work can be done when the weather is cool or rainy, or when there is a high wind.

Altitude, latitude, moisture, and soil also affect management (see Chapter XVIII, "Sources of Nectar and Pollen"). As one goes north, the nectarflow increases in intensity but the period of flow is shorter. The beginning and end of the honeyflows are also more sharply marked. Farther south, there is a gradual increase and decrease in the nectarflow and its intensity is not as great. Generally speaking, the farther north one goes in good beekeeping territory, the more certain are the crops. Farther south, the beekeeper finds his greatest problem in preventing his bees from converting everything they gather into brood.

Enough has been said to indicate that natural factors have a great deal to do with the success of a location. If a location is not suitable because of natural factors beyond the control of the beekeeper, the only remedy is to seek a more desirable place.

## Keeping Useful Records

Individual colony records are an aid in bringing colonies which are not normal into good condition as rapidly as possible. Perhaps the most useful application of individual colony records is in selecting colonies which have superior queens from which breeding may be attempted. These colonies should be checked for their ability to gather an extra-large crop, for queens that lay vigorously and regularly, and for progeny that is of good disposition, not inclined to swarm, and winters well.

Individual colony records may be marked on the top of the cover or on the sides or back of the hive body. The markings may be made with a crayon or a waterproof ink pencil, or by some marking system, such as bricks or sticks used in different positions on top of the hive.

Operation records are more important than colony records. These may be kept in a book carried by the beekeeper in which he sets down the cost of labor, mileage, the materials used, and the attention required on the next visit. Thus, the cost of operation and the frequency of visits are recorded, and the beekeeper knows whether his beekeeping is paying or not. Pertinent notes may be added about variations in the honeyflow, the season, extent of the crop, weather, and other significant factors. When it is possible to establish a scale colony in the home yard, the recording of the seasonal fluctuations is a valuable addition to record keeping.

Usually, each beekeeper has a pet method of keeping records which he finds best for his own purposes. Some use a printed form on which notations are kept. At the end of a year, a summary is made of profits and losses and a study made to determine how operation costs may be reduced. It is often possible through such a study to learn how to combine work so that fewer visits to the yards are necessary or to accomplish work in a shorter time, cutting costs to the lowest point. There is something fascinating about going back over the past to measure significant facts and to broaden one's memory by the history which records reveal.

# X. *Management for Extracted Honey Production*

BY G. H. CALE*

THE honey-bee colony must come through winter and into early spring with enough of the winter population of worker bees remaining to support the queen in her egg laying and to care for the brood, so that the colony will increase in population until it reaches a high point at the beginning of the main honeyflow. This is a matter of timing and expert fall management has much to do with it. Dr. Farrar (see Chapter XIV, "The Overwintering of Productive Colonies") states that each colony must be conditioned in the fall, if it is to be the best in the spring.

When the food reserves of honey and pollen are sufficient for winter, many colonies with capable and efficient queens will begin brood rearing in the latter part of winter, and will add enough young bees to replace their winter population in early spring. Colonies with insufficient stores or with less satisfactory queens will have little, if any, winter brood. They may not start brood rearing until spring is at hand, and often they are unable to build to peak strength by flow time.

It is usually said that the beekeeper's year begins in the fall. The entire year, from one fall to the next, may be divided into the inactive period of late fall, the winter period, early spring, the interval before the main honeyflow, the honeyflow itself, and the period following the honeyflow which includes most of the fall.

Management in each period is directed toward the cardinal objective of producing a maximum honey crop during the coming honeyflow. The greater the number of colonies there are in operation the less likely it will be that every colony will be in the best condition. Nevertheless, each operator should manage his colonies so that as many as possible are in ideal condition at all times.

Seasonal differences, the abundance of nectar and pollen plants, locations, weather, and soils—all affect management. There is no rule or procedure that may be followed from year to year. It is possible only to direct attention to fundamentals; the beekeeper must adapt them to his own circumstances.

---

*Gladstone H. Cale. Managing editor of the *American Bee Journal.* Manager of the apiaries of Dadant & Sons and operator of his own apiaries.

The major portion of the total honey crop of the United States is harvested from May to September, although in the South and in California crops are produced as early as March and April.[1] It is likely that at least half of the total crop of the country is produced before July 1. It follows, therefore, that the inactive, preflow, honeyflow, and afterflow periods occur at about the same time over most of the country. Although this discussion of seasonal management is based on beekeeping in the Midwest, beekeepers in other areas will be able to apply the same procedures.

Inasmuch as Dr. Farrar in Chapter XIV, "The Overwintering of Productive Colonies," discusses the fall and winter periods, the discussion of management in this chapter starts with the spring period.

## Early Spring

All colonies should be given a quick examination as early in spring as possible. It is not necessary to wait until bees fly freely every day. If the colonies are in two or more full-depth bodies or if they are in one hive body with a food chamber, separate the top body and tip it back without removing the cover on top. Look closely among the combs to see if there is brood present. If there is no brood, the colony is most likely queenless. If the queen has failed and has become a drone layer, that will be shown by the predominance of drone brood.

A colony with a strong cluster of bees and a normal amount of worker brood needs little attention unless it is light in stores. This may be determined by lifting the hive at the back. If it is light in weight, the colony should be opened and the combs examined for stores of honey and pollen. If lacking in honey stores, the colony will need to be fed sugar sirup or given combs of honey. If there is little stored pollen, the colony should be fed pollen substitute or pollen supplement, especially if early spring sources are not available or weather is not satisfactory for daily flights.

Hives in which bees have died in winter should be removed from the apiary; the combs should be examined carefully for the possible presence of disease. If the combs are free of disease, the hives should be cleaned and made ready for future use. Weak or indifferent colonies may be removed from the outyards to the home yard where they can be managed with less expense or disposed of later. If a queenless colony has an abundance of bees, it should either be given a new queen obtained from a southern breeder or should be given a comb containing eggs or very young brood, with the hope that the bees will raise a new queen which will mate and provide the colony with a laying queen.

Any work in early spring must be done quickly and with care, stopping if robbing becomes apparent. See that the entrances of the colonies

[1] Voorhies, Edwin C., Frank E. Todd, and J. K. Galbraith. 1933. Economic aspects of the bee industry. *Univ. of Calif. Agr. Exp. Sta. Bull.* 555.

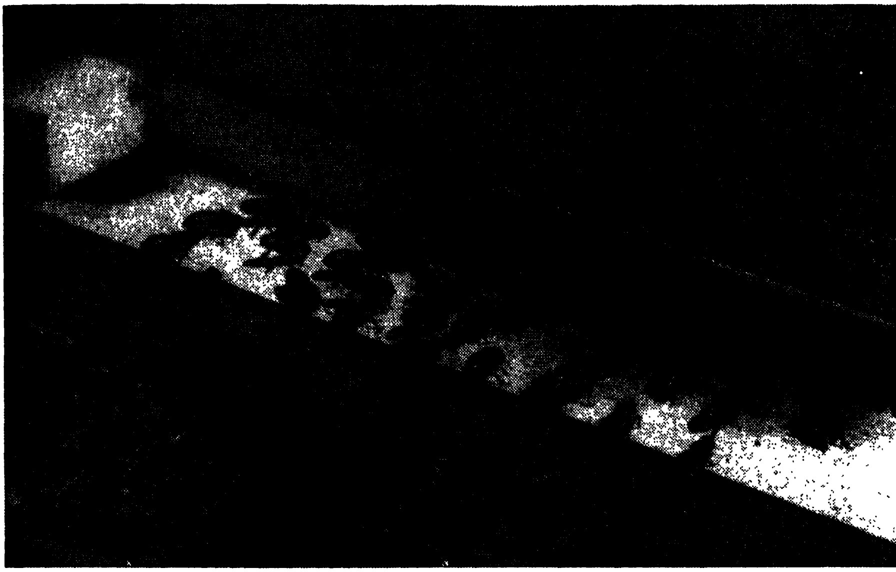


FIGURE 145. It is a good practice to reduce the entrances of all colonies in the spring. (*Photo courtesy Fred Chadde*)

are clear of obstructions so the bees will have free flight, and reduce all entrances (Fig. 145) so that the colonies will be able to guard against intrusion by robber bees. The bee yard should be cleaned of rubbish and trash ahead of the working season, and all hives that are out of position should be lined up and leveled. Bees have greater need for water for brood rearing in spring than at any other time; if an abundant natural source is not at hand, watering places will have to be provided.

Colonies that have been wrapped with tar paper or similar material and those that have been lightly packed can have their protective covering removed in early spring. If the colonies have been heavily packed for winter, the packing should be left on until the season has advanced to a daily maximum temperature of about 60° F. These colonies expand their brood area in late winter or early spring over a greater comb surface than those with light packing. Early removal of the heavy packing may cause loss of brood by chilling because of the inability of the bees to keep all of the brood warm. Heavily packed colonies should be amply provisioned with stores of honey and pollen in the fall so that it will not be necessary to remove the packing before warm weather occurs. If colonies have been wintered in cellars, they should be brought out as soon as the weather is warm enough for flight.

Colonies in spring often lose adult bees faster than newly emerged bees can take their place. This is frequently referred to as *spring dwindling.* This is usually present in most colonies, but it is serious only in those that lose so many old bees in proportion to the emergence of young

ones that the colony reaches a low point in population before there are enough young bees to balance the loss. It is more apparent in some colonies than in others, and it is more severe in some springs than in others. Colonies with an abundance of reserve honey and pollen in late fall and with a strong winter population begin brood rearing in late winter and are able to replace their loss in adult population. Some colonies may even show an increase in the number of bees when winter is over.

Sometimes dwindling is caused by pollen that is not suitable for brood rearing. There is evidence that some early pollens are actually poisonous to brood and so contribute to this condition (see Chapter XXII, "Injury to Bees by Poisoning").

When the population of the colony in early spring steadily declines, it may also be due to the failure of the queen. In such cases, the old queen should be removed and replaced with a new one, introduced in a mailing cage or in a push-in cage during a period of early bloom. Additional combs of brood and bees from colonies that can spare them will help bolster the colony.

The loss of adult bees in early spring may also be due to Nosema disease, a disease of the adult honey bee that is general throughout the country. The losses of adult bees often are not easily detected. Careful scrutiny may detect bees crawling about on the ground in front of an occasional colony in the apiary. In some seasons, Nosema disease may cause such extensive losses that many colonies are unable to reach producing strength by the time of the honeyflow. For additional information on adult bee diseases, see Chapter XXIII, "Diseases and Enemies of the Honey Bee."

When spring dwindling is common to all colonies in the apiary, it is difficult to remedy and it may be necessary to unite many colonies. If weak colonies are headed by good laying queens, it is best to try to build up the individual colonies during spring, uniting them just before the honeyflow rather than at an earlier time.

When early bloom, such as dandelion or fruit bloom, is sufficient to provide colonies with nectar, they may be opened and examined more freely and thoroughly than previously. A careful examination of the brood nest is advisable to make sure that the queen in each colony is satisfactory, that food is present in sufficient quantity, and that there is no disease of the brood.

Some beekeepers have difficulty in recognizing brood diseases, the most serious being American foulbrood. To make certain that the brood is free from this disease, examine the cells of brood in a comb from which bees are emerging. Any cells that are still capped in an area from which brood is emerging should be opened and examined for any abnormal condition of the brood. If any colony is found to be infected with American foulbrood, it is best to dispose of it at once.

To prevent the occurrence of American foulbrood the use of resistant stock is highly advisable. Colonies headed by queens bred for resistance

to this disease may be managed without the incessant close attention required with common stock. However, even when resistant stock is used, disease may be found, particularly following the supersedure of the queen, if the new queen mates with a drone of susceptible stock.

Sulfathiazole may be used efficiently in the prevention of American foulbrood by giving each colony in spring one or two 10-pound feedings of sugar sirup containing a fourth of a teaspoon of soluble sodium sulfathiazole, or a half-gram veterinary tablet, dissolved in each pail of feed. The same procedure is advisable when installing package bees. The feeding of sulfathiazole should not be continued after supers are added to the colony, thus avoiding storage of the sirup in super combs where it later may become mixed with the surplus honey.

The use of sulfathiazole to cure a colony infected with American foulbrood is seldom advisable.[2] It is a much safer practice to confine the use of this drug to preventive measures, and any diseased colonies which may be found at any time should be destroyed. In practice, the use of good queens bred for resistance to American foulbrood plus preventive feeding of sulfathiazole in sugar sirup practically eliminates the bother and expense previously experienced by the beekeeper.

## The Period Before the Flow

When brood rearing begins in late winter or in early spring, the brood area is usually to be found in the upper portion of the brood nest at the time of the first thorough examination of the colony. The brood area will mainly be in the top hive body when two or more bodies are used for wintering the colony, or in the super and the top of the brood combs of the hive body when the colony has been wintered in a single hive body with a shallow super used as a food chamber. Inasmuch as the tendency of the colony is to expand the brood nest upward, the queen will not readily move down to empty combs. Therefore, it is good practice to set the top hive body or super on the bottom board, setting the bottom hive body on top, thus reversing the parts. This reversal brings most of the brood to the lower position (Fig. 146) with a less amount of brood at the top. It also breaks the circle of the brood, placing the two segments in inverse positions. The queen then moves upward readily, first into the empty portions of the brood area and then into the empty combs above. At the same time, the house bees rearrange the stores of the colony around the new brood area. This stimulates the colony to greatly increase its population. With a good queen in a populous colony, it may be necessary to reverse the brood bodies again before the flow occurs.

Before the beginning of the main honeyflow, the bodies that earlier were placed on the bottom boards in the reverse position will have be-

[2]Haseman, L. and L. F. Childers. 1944. Controlling American foulbrood with sulfa drugs. *Mo. Agr. Exp. Sta. Bull.* 482.

come empty through the emergence of the brood and the rearrangement of the stores of honey. They then should be returned to their original positions. When the flow begins, they will be used for storing the first part of the flow. At the end of the season, these bodies will be well provisioned with honey and pollen and should be left on the colonies as food reservoirs for winter. During the flow, supers needed for storage of surplus honey are added above these food chambers.

Some queens confine their egg laying to the center combs of the brood nest because there are combs of honey or pollen on each side. There may be empty combs near the sides of the hive, but the queen does not use them and the brood area is confined as effectively as though the hive were smaller. The empty side combs may be moved in next to the brood area where they will soon be occupied by the queen, thus expanding the brood nest (Fig. 147). Combs not suitable for brood rearing should be removed and either replaced with good combs or frames containing full sheets of comb foundation. Remember that comb foundation is not drawn into comb in the brood nest as satisfactorily as it is drawn above the brood nest in a good honeyflow (see Chapter IX, "Common Practices in Management").

The period just before the main honeyflow is usually when colonies are most apt to exhaust their reserve stores. In the earlier season, relatively few colonies may have needed feed, but there will be some colonies that will require feed at this time even though an abundance of stores was left with them the previous fall. It is not unusual for populous colonies, with a large amount of brood to feed, to use up all of the available

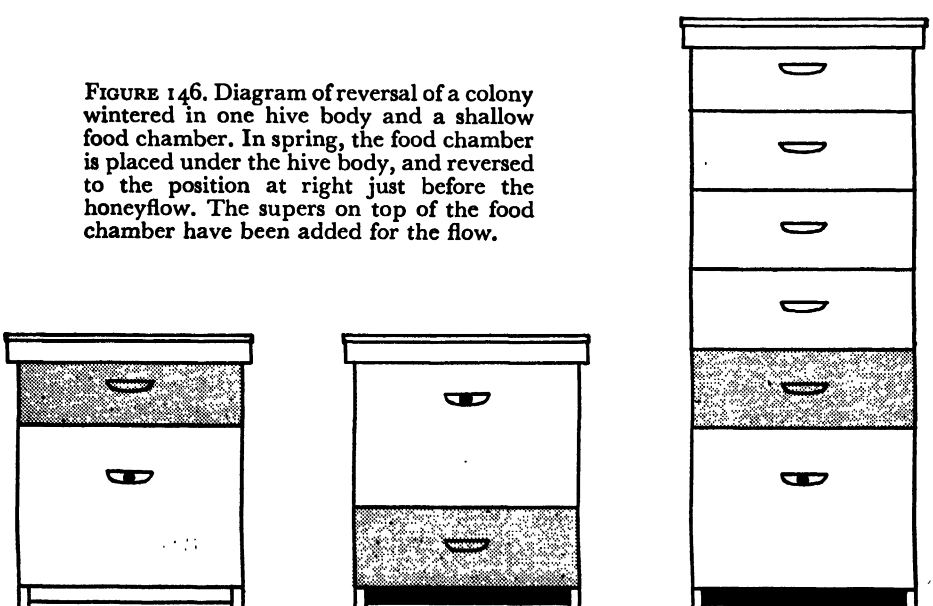


FIGURE 146. Diagram of reversal of a colony wintered in one hive body and a shallow food chamber. In spring, the food chamber is placed under the hive body, and reversed to the position at right just before the honeyflow. The supers on top of the food chamber have been added for the flow.

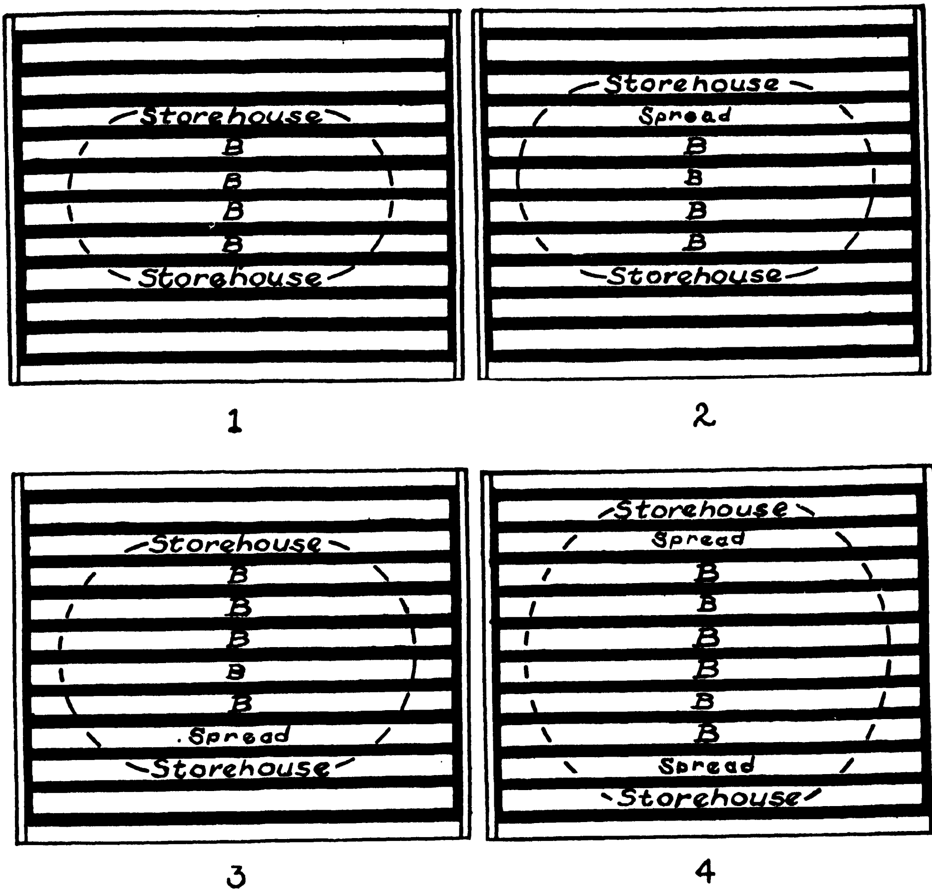



FIGURE 147. Diagram of expanding the brood nest. With four fairly well filled brood combs flanked by stores (1) in fruit bloom, one empty comb is moved in (designated as "spread" in 2), a week later another is moved in (3), and about 10 days later two empty combs are moved in (4).

food supply and even to die of starvation. In this period when not enough nectar is available to supply the food requirements of the colony, the careful beekeeper will make sure that all colonies have an ample supply of food so that brood rearing can continue without interruption.

When the development of the colony starts with the beginning of brood rearing in late winter or early spring, with a vigorous young queen, an abundant supply of food, and sufficient comb area for brood rearing, the colony's peak of population may occur at the start of the honeyflow, and the ideal in management has been attained. It usually requires 8 to 10 weeks between the time that spring begins and the start of the honeyflow to bring about this favorable occurrence. In other words, a fortunate conjunction of the peak in colony population and the beginning of the main honeyflow makes honey production relatively easy. Either too long

a period before the flow or too short a time, makes beekeeping more difficult.

If the honeyflow occurs in less than 8 to 10 weeks from the beginning of spring, there is often too little time for the colony to reach proper strength without the most expert care. It requires prolific young queens, an ample supply of food, and effective intelligent management—plus ideal conditions of weather, an abundance of honey and pollen plants, and freedom from diseases—to produce a maximum honey crop. If conditions are not ideal, it may be necessary to bolster colonies with queenless packages or to unite colonies prior to the honeyflow.

When the honeyflow occurs 12 weeks or more after the beginning of spring, the colony may have reached its peak of population before the start of the flow. It either will swarm before the main honeyflow or lose its colony morale and decline in its honey-gathering ability. To delay the peak of population in a long period before the honeyflow, colonies may be divided during the time of early flow from dandelion, fruit bloom, or other sources. A new queen is given to the queenless part and each division is allowed to grow until the honeyflow begins. The two parts may then be united or may be operated individually, if there has been time for each part to achieve a satisfactory population of field bees for the flow.

This period before the honeyflow is also the time when many colonies follow a natural instinct to divide their populations through swarming. Because neither the parent colony nor the swarm will gather as much honey as the original colony, swarming should be prevented or controlled by proper management. For information on swarm prevention and control, see Chapter IX, "Common Practices in Management."

## The Honeyflow Period

It will now be assumed that we are entering the honeyflow with populous colonies that have not swarmed and are headed by queens able to maintain colony strength through the honeyflow period. There is little else that may be done to improve the colony; it is ready for the honeyflow.

Now is the time when supering colonies for the surplus honey crop must be carried on in earnest. When the nectar is brought in from the fields by the field bees, it is given to house bees who first may place it in temporary storage in the cells of combs in the brood nest. Later it is removed and the house bees evaporate its water content and invert the complex sugars, and place it in more permanent storage in the super combs.

Most beekeepers regard the super as merely a shallow or full-depth body containing a set of combs in which surplus honey is stored, but it is more than that. The super is one of the most significant pieces of equipment in the apiary. It is the place where bees congregate when working the nectar being brought in from the fields. It serves both for storage of honey and for distributing the population of the colony in that the bees

are not confined to the brood area. The congestion of the brood area is one factor always present in swarming. Supering, therefore, becomes a part of management of greater significance than is often realized.

### Supering the Colonies

The importance of giving supers early enough to provide room for the bees to congregate while they are working the nectar that is being brought in daily from the fields cannot be stressed too much. Supering extends throughout the honeyflow period, and the way in which the beekeeper supplies additional supers is important inasmuch as it influences the morale of the colony and, in turn, the size of the crop.

On the other hand, if supers of drawn combs are given when nectar is not available, it is an invitation for the queen to use the combs for brood rearing, particularly if the supers are full-depth hive bodies. Some beekeepers use queen excluders to prevent the queen from using the supers for brood rearing. However, the use of the queen excluder is often considered an impediment to the bees during the honeyflow period.

When shallow extracting supers are used, the tendency for the queen to produce brood in them is less than when full-depth supers are used. When it becomes necessary to supply super room for colony expansion previous to the honeyflow, the addition of one shallow super is usually sufficient. If the shallow combs are used by the queen, they become occupied with honey as soon as the brood emerges, and the queen returns to the full-depth brood combs below.

The first supers given above the food chambers in the start of the flow should be supers of drawn combs. When the combs along the tops of the frames in the food chamber or the brood nest are whitened with freshly secreted beeswax, any delay in supering is bound to bring on swarming conditions. If possible, supers should be added just before this whitening of the combs.

As the bees require more room, the addition of supers of drawn combs may be made on top of those already in use. When the bees occupy the top super, storing nectar and honey in it freely, it is time to give another one on top. This *top supering* is continued until the flow begins to taper off and no further room is considered necessary.

If supers of drawn combs are not available, it is necessary to use supers containing frames of comb foundation. It is a good plan to replace one or more of the frames of foundation with drawn combs to induce the bees to start to work the foundation more readily. The adding of drawn combs in this manner is referred to as *baiting* the super.

The supers containing comb foundation may be added next to the brood nest during the heaviest part of the honeyflow where they will be quickly drawn into combs for honey storage. They will not be drawn as readily higher up in the stack of supers above the brood nest, particularly at the very top. Nevertheless, when supers of drawn combs are added for

an immediate requirement for room for honey storage, it often is a good plan to put the super of foundation one or two positions above the brood nest. Here, it will be occupied by the bees in a good honeyflow and partly drawn into combs. On the next visit, it may be placed below the supers of drawn combs, and another foundation super added in its former position. This may continue as long as the bees will draw foundation into comb.

Another way to have foundation drawn into combs is to select a few colonies that are effective comb builders, and to remove most of the supers of drawn combs from them, adding foundation supers in their places. When these foundation supers are partly drawn, they can be removed and used on other colonies. The supers of combs that were first removed from the colonies can then be returned.

The use of foundation supers is sometimes an aid in the prevention of swarming. At the beginning of the honeyflow, bees sometimes secrete more beeswax than they can use. If supers of drawn combs are given to the colonies, the bees may not have sufficient opportunity to use the wax which they are secreting. The giving of supers of comb foundation affords them ample opportunity to use this wax, and at the same time removes these bees from the brood nest. At such a time the foundation is quickly drawn into combs and the colony seems to be content to remain at work, and is less apt to initiate swarming.

When bees will no longer draw foundation and all the comb supers are in use, and yet more room is needed for honey storage, it becomes necessary to remove supers which have been completely filled with honey and the cells sealed. These are then extracted and the supers of empty combs returned to the colonies, thus providing room for the balance of the crop.

At this time of the year, it is sometimes difficult and occasionally impossible to get over roads with truck loads of supers. To avoid this, supers may be stored in advance on platforms at the yards, and the stacks of supers made bee tight and covered to keep them clean and dry. They are then available when needed in spite of road conditions. Sometimes, a few more supers are taken to a yard than are needed for immediate use. These supers can be stored above some of the colonies over the inner cover with the center hole open and the outer cover placed on top.

It is difficult to judge how much room to give colonies when the flow is at its best. Colonies on scales (Fig. 148) have registered gains of from 10 to 25 pounds of unripe honey in a single day. Twenty-five pounds of nectar, as stored temporarily by the bees in a heavy flow, is sufficient to fill an average shallow super of combs and to partially fill a second one. The gain in 2 days often will completely fill a shallow super with ripe honey. Thus the importance of giving sufficient room well in advance of need is demonstrated.

It is usually good practice to keep colonies supplied with at least one super ahead of their needs. Frequently, two or more supers are given to

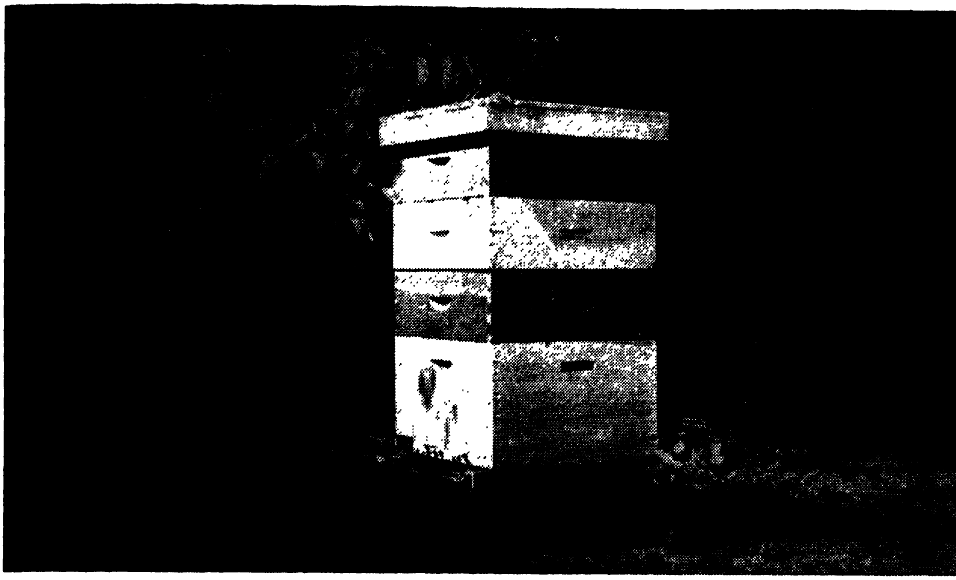


FIGURE 148. A scale colony in the apiary at Pellett Gardens where colonies of bees are provided to determine the value of flowering plants as honey sources.

strong colonies at one time, particularly in an exceptionally heavy and fast honeyflow. However, it is easy to give colonies more supers than they need toward the latter part of the honeyflow, and the period may end with honey distributed through a large number of combs instead of being concentrated in a few.

Toward the end of the flow when it is doubtful that bees will need additional room for honey storage, a super of combs can be placed over the inner cover with the center hole open, or over the oil cloth with one corner turned back. If the colony really needs this additional room, they will go up through the space provided to store honey in the super; otherwise they will remain below, finishing the supers there. This plan also is useful when the beekeeper is not sure that he will be able to return to the yard in time to give additional room, and colonies already have considerable comb space partially filled with honey.

In estimating the number of supers that may be needed for each colony during the honeyflow, figure the number required in an average flow, determined by experience over a period of years. In most locations, three or four supers to the colony are sufficient. In years when the honeyflow is more abundant than others, and more room is required, supers of honey will have to be extracted and the empty combs returned to the colonies. This practice is referred to as *rotating* the supers. In years of light honeyflows, supers containing empty combs must be stored in the honey house, or other place, and protected from damage by the larvae of the wax moth, or by mice and other rodents (see Chapter XXIII, "Diseases and Enemies of the Honey Bee").

## Colony Management During the Flow

The honeyflow period is a good time to draw full-depth combs for use in the brood nest in succeeding years. The culling of combs that are not suitable for brood rearing is a good beekeeping practice that has been sadly neglected. The best time to draw full-depth combs for replacing them is during a period of good honeyflow, and the bodies containing the frames of full sheets of comb foundation should be placed immediately above the brood nest (see Chapter IX, "Common Practices in Management").

This also is the time to requeen colonies that are not doing well in producing a surplus crop of honey. Inasmuch as requeening at this time requires that the laying queen be replaced with another whose egg-laying activity will at least balance or exceed her antecedent, it is desirable that the new queen be brought to this condition in a nucleus. Such requeening practice has resulted in surprisingly increased crops of honey.

The honeyflow period also is a good time for collection of pollen for use in the succeeding spring in the preparation of pollen supplements. Inasmuch as the use of pollen traps robs the colonies of incoming pollen and confuses the incoming and outgoing field bees, it is advisable to switch traps every 10 days to other colonies (see Chapter XIV, "The Overwintering of Productive Colonies").

Sometimes it is desirable to make "summer" divides for increase or for replacing colonies. The success of divisions at this time is dependent on a sufficient time for them to build to colony strength before winter and an ample supply of nectar and pollen in the fall period to provide colony support and stores for winter. The theory behind such practice is that toward the end of the honeyflow, many colonies are strong with more brood than they may require. The usual method is to remove combs of brood and bees from these colonies, placing them in a new hive in a new location, and introducing a new queen. Should such divisions be unable to build to full strength with ample stores for wintering, they may either be united or wintered as nuclei over a screen above normal colonies.

There comes a time when the intensity of the honeyflow diminishes, and soon will be over. If a scale colony is in use to indicate the daily gain or loss, the amount of nectar being gathered each day remains about the same, and then begins to drop slowly. The addition of supers may no longer be necessary because there is sufficient room in which the bees can store the remainder of the crop. It is well to consider that the amount of space occupied by incoming nectar will be reduced as the honey is ripened and stored permanently. Gradually the whole stack of supers is filled and a sufficient amount of honey is stored in the brood nest for winter use.

This is the time to take supers from colonies that have been given too many. They may be given to those colonies that need additional storage

space or returned to the permanent super storage place, thus ending the season with as few unoccupied supers as possible. Above all, this is a period of precise and careful management for it should accomplish storage of honey compactly around the brood area where it is available to the winter cluster.

## Removing the Extracted Honey Crop

The beekeeper who has managed supering correctly will have most of the supers well filled and ready to remove during the last of the honeyflow period before robbing has become prevalent. Usually, it is possible to remove all but one or two supers at this time leaving the balance on the colonies for the bees to use in storing the rest of the nectar which may be gathered. Thus, the intense robbing, which occurs when all supers are left and removed after the flow has ceased, is avoided. The few remaining supers may later be removed quickly so that robbing does not impose a serious problem.

It is a convenient and proper time when the first supers are removed, to look over the brood of each colony to determine the condition of the queen, whether disease is present, and to ascertain any other needs of the colony. If colonies are found to be diseased, they should be disposed of at once (see Chapter XXIII, "Diseases and Enemies of the Honey Bee"). Supers of honey from diseased colonies should be segregated from the rest of the crop and extracted after all the other honey has passed through the extracting equipment. When these supers have been extracted, the equipment should be thoroughly cleaned and disinfected, and the supers should be disposed of as desired.

When the supers are taken from the colonies, a well-filled super with an abundance of pollen and honey should be left with each one. Usually, this will be the food chamber which was returned to its position above the brood nest before the beginning of the flow. This applies, of course, to the Modified Dadant system of management and to the two-story Langstroth system if an adequate reserve of stores has not been established in the brood bodies. The two-story, and especially the three-story, Langstroth colony at this time of the year should have adequate provisions for winter, however.

Many beekeepers still remove supers of honey by shaking and brushing the bees off the individual combs of honey, returning the combs to the supers, and loading them on trucks or carrying them into the honey house. Some insert bee escapes in the hole in the center of the inner covers and place the inner covers under the supers to be removed. When equipped and used in this manner, the inner cover sometimes is called an *escape board.* If there are cracks or holes opening into the supers of honey above the escape boards, they must be closed tightly in some way. Pieces of cloth, paper, or even mud may be used to close these openings. This

will prevent robbers from reaching the honey while the escapes are in use. As soon as the supers are free of bees they may be removed from the colonies. In exceptionally hot weather, the escape boards should be placed on the colonies the afternoon before the honey is to be removed; if left on for too long in very warm weather, the combs of honey will melt or break down in the supers. In cool weather, a longer time is required for the bees to find their way to the brood nest below.

When removing honey in cold weather, supers may often be taken from colonies without any preparation of this kind. The bees will have left most of the super combs and will have clustered below in the brood nest and in the first super or food chamber. If there are a few bees remaining in the lower supers, they can be shaken off the combs with little difficulty.

### Removing Supers with Acid

The use of chemically pure carbolic acid in removing the extracted honey crop is swift, effective, and economical. Most operators who have tried it would not return to any other method. This has been made possible by the production of pure carbolic acid in crystal form which may be liquefied easily by adding an equal portion of warm water. If properly used, pure carbolic acid does not affect the aroma and flavor of honey as did the impure product that had been tried previously.

*It must be said forcibly that carbolic acid is not a harmless chemical.* It burns flesh severely and rapidly; a drop of acid in the eye could result in permanent injury. Carbolic-acid containers should be marked conspicuously and never placed where this chemical may be mistaken for some other substance, or where children will be able to reach it.

The effects of the acid can be neutralized immediately with grain alcohol, or denatured alcohol, and a bottle should always be carried whenever carbolic acid is used. The moment that a drop of acid touches the flesh, the alcohol should be applied to the spot liberally. If alcohol is not available, thorough washing with water will help to minimize its effect.

Figure 149. Carefully sprinkle the cloth side of the acid board with just enough carbolic acid to wet the cloth.

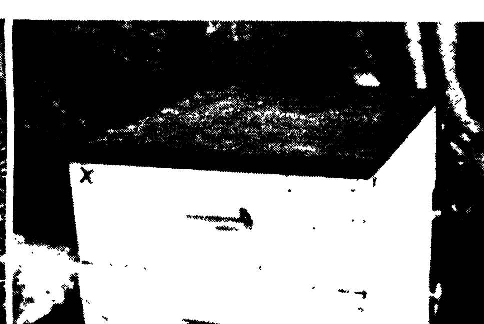




Figure 150. The acid board in position on top of the supers enables the beekeeper to "frisk" off the honey.

FIGURE 151. The top super, which the bees have left is ready to be removed from the colony. Notice the handy V-shaped block for holding up the front of the super until it can be lifted.

When distributing the acid on the acid boards, it is recommended that the container be handled with rubber gloves, or bee gloves, and that goggles be worn to protect the eyes.

The chemically pure acid is obtained in bottles or tin containers. When liquefied, it may be poured into pint- or quart-sized bottles and each fitted with a sprinkler top similar to those used for sprinkling clothes. A pound bottle of acid will usually be sufficient to remove the supers from 50 to 100 colonies in a single period of operation, the amount required depending on the weather and the number of supers to be removed.

In removing supers of honey by this method, an acid board is used (see Chapter VI, "Beekeeping Equipment"). Most any similar contrivance is also suitable. An inner cover, with a piece of burlap or cloth tacked on the inside of the rim, can be inverted and used for this purpose.

To prepare the boards for use, shake the liquid acid from the sprinkler bottle over the cloth (Fig. 149), wetting it well but applying only enough acid to produce strong fumes. Never use so much acid that drops of it will fall on the frames or combs of honey when the board is in use. Depending on the rapidity with which the acid boards repel the bees, anywhere from five to ten boards may be used at one time. A sufficient number should be employed so that it is possible to take supers away in steady succession without having to wait for the bees to leave the supers, and so that the boards do not remain on the colonies for too long a period.

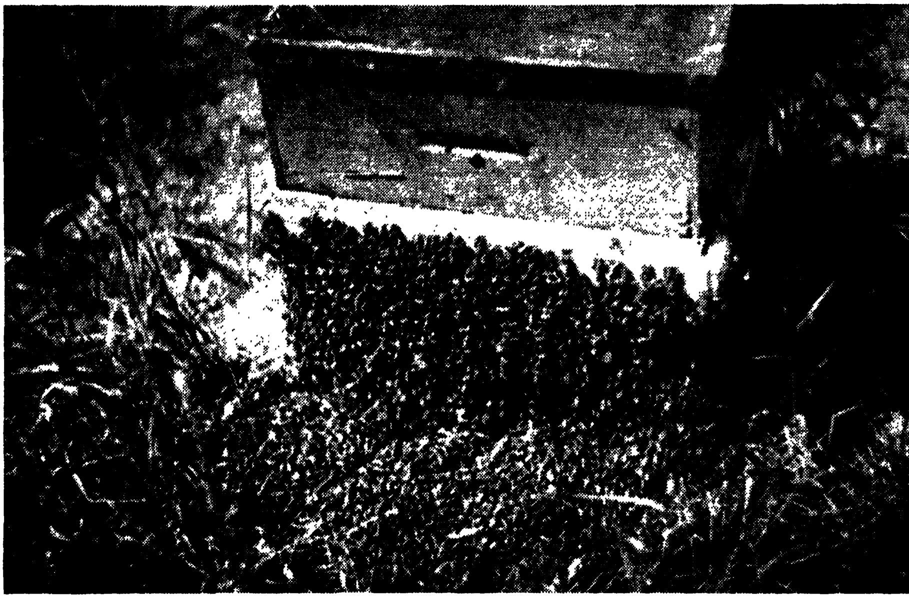


FIGURE 152. When the bees are rushing out of the entrance of the hive in this manner, the acid board should be removed at once.

After the acid is sprinkled on the cloth of the acid boards, they are ready to be placed over the supers. The outer cover and the inner cover are removed and the acid board is placed over the colony with the cloth side down (Fig. 150). The boards are added in this manner from hive to hive until all of them are in position. In ideal weather, the bees will leave the top super in about 5 minutes; the top super then is removed (Fig. 151) and the acid board placed over the next super of the colony. Under favorable conditions, two or three men working from colony to colony, taking off the top supers and returning for the next ones in rotation, will be able to remove 80 to 100 supers in a couple of hours.

When the boards are in use over the supers on top of the colony, the heat from the colony and the sun volatilizes the acid. The fumes of the acid are irritating to the bees which try to get away from the source of their discomfort. They quickly leave the super that is directly under the acid board; they will even leave the hive, crowding out at the entrance if the acid board is left on too long.

During a hot, quiet day of full sunshine the bees leave the supers readily and, as the number of supers above each colony is reduced, the bees finally start to come out of the entrance of the hive (Fig. 152). If, however, they begin to fly to any extent, the boards must be removed at once. Never leave the acid boards on long enough to drive the bees into the air. When excessive flight has been established, bees of different colonies will unite in the air, the queens may leave the hives and be lost,

FIGURE 153. Loading the truck with supers of honey. Notice the inclined walkway or gangplank at the rear of the truck.

and drifting becomes so general that some colonies are depleted in population and others are greatly strengthened.

When the weather is cool or when the sun is under the clouds and the day is windy, the acid will not work as rapidly as in calm, sunny, warm weather. Then, a greater number of acid boards will have to be used so that bees will leave the supers with sufficient rapidity to work from colony to colony without delay. In late fall when it is cold, the use of acid often is unsatisfactory.

Inasmuch as carbolic acid is repellent to the bees, it also may be used to suppress robbing. Robber cloths, on which carbolic acid is lightly sprinkled, or wet with water containing a small amount of acid, may be used to cover the tops of hives, or to lay over supers or combs that are set away from the hive temporarily. For additional information on the use of robber cloths, see Chapter IX, "Common Practices in Management."

The cloths or tarpaulins used to cover supers of honey on the truck during loading and while hauling to the honey house also can be sprayed or sprinkled in a similar manner. This helps to keep down robbing when the supers are being removed at a time when there is little nectar in the fields. It is best to have a truck with tight sides and bottom so that the bees cannot get to the supers in this way. Some operators enclose the body of the truck with screen wire.

In loading the supers at the yard, the truck should be driven close to the hives from which the supers are to be taken, but out of line of flight

of the field bees. The supers of honey may be loaded (Fig. 153) on strips of paper that cover the bed of the truck. As the truck is unloaded at the honey house, the papers can be rolled back and finally removed, leaving the floor of the truck clean. Supers also can be stacked on platforms or hauling boards set on the bed of the truck.

A large cloth or tarpaulin is placed over the cab of the truck, one end extending onto the front of the truck bed (Fig. 154). As fast as the supers are placed in position on the truck bed, they are covered temporarily with acid boards turned upside down to repel any robbers that may be attracted to the supers. When the first tier of stacks of supers at the front of the truck has reached the desired height, the boards are removed and the cloth or tarpaulin pulled back over the supers. The next tier of stacks is handled in the same manner, and this is continued until the load is finished.

A long board with wooden treads for secure footing, and with spikes at the underside at the ground end, may be placed at the rear of the truck bed. This enables the workers to walk up the board and into the truck bed to place the supers where they are wanted. A set of temporary steps may also be used. Bent iron extensions at the top of the steps slip into the stake holes at the rear of the truck bed, and the bottom of the steps rests on the ground. These steps are placed under the truck bed and secured when not in use.

If the bed of the truck and the floor of the honey house are at the same level, the platforms on which the supers are stacked can be moved

FIGURE 154. The super is carried to the truck in this position.

directly to any desired place in the honey house (see Chapter XI, "Extracting the Honey Crop"). If the level of the honey house floor is higher than that of the truck bed, a heavy screw or hydraulic jack can be placed under the truck bed to raise it to the desired height. When supers are unloaded at the honey house, the stacks should be left uncovered for a few days so that the acid fumes will leave the supers.

It is surprising how rapidly the supers of honey can be removed from the colonies and delivered to the honey house when the methods and equipment are suitable for the job. Several loads of honey thus may be brought to a central extracting plant in a day's time.

## Care of Bees in the Fall

Now that the season's crop of honey has been removed from the colonies leaving a full supply of stores for winter, we have reached the fall period.

This is the time of year when the influence of the queen is greatly felt. Some queens continue egg laying until late in fall, even after the beginning of cold weather. There also is a marked difference in the rate at which queens lay their eggs. Some queens reduce egg laying at a much quicker rate than others, although there may be some brood in the colonies throughout the entire fall period.

The ideal queen is one whose egg-laying rate is high and continues well into late fall, thus furnishing a populous cluster of young bees for winter. The stronger the colonies are with respect to a population of young bees before winter, the better they will be able to survive the winter period. A large colony of relatively young bees, well supplied with stores of honey and pollen, also will be able to rear brood in the latter part of winter and in early spring. Such colonies will usually come through the following spring with little spring dwindling, and, with proper management of their steadily increasing populations, can be brought to the honeyflow in optimum condition for gathering a maximum crop.

It is of utmost importance, therefore, to make sure that each colony has a queen which is able to give an ideal performance. New queens should be introduced early enough to begin egg laying in late summer and early fall. Queens introduced late in the season are unable to produce a desirable population of young bees for the winter cluster.

It is also important in the fall to make sure that each colony has an abundance of reserve stores of honey and pollen. When storing pollen, particularly toward the end of the season, bees seldom fill the cells more than two-thirds to three-fourths full. The bees then often finish filling these cells with honey and seal them with wax cappings, so that the comb appears to be full of honey. When the food chamber and brood nest are properly provisioned with both honey and pollen, and the colony has a

young queen and a strong winter cluster, the colony is in ideal condition for winter.

Colonies that are not in first-class condition for winter, should be united with other colonies. Those that are in poor condition should have their bees shaken from the combs in front of other colonies, and the equipment should be removed from the yard and placed in storage. The equipment should be carefully saved and filled again with bees the following season.

FIGURE 154a. With the producing season over, this apiary is ready for winter's storms and frigid air. (*Photo by Killion Photo Service*)

# XI. *Extracting the Honey Crop*

BY ROY A. GROUT*

THE harvesting of extracted honey is completed in the extracting plant, commonly called the honey house. The honey house of today, as well as the equipment it contains, is largely the result of the ingenuity of beekeepers, and has become the center of beekeeping operations. Sechrist[1] has said, "As the queen bee is the heart of the colony, so the honey house is the heart of the apiary. Into it, through it, and out of it flow all of the currents of beekeeping activity throughout the season."

The removal of liquid honey from the combs is accomplished in the honey extractor. The invention of the honey extractor ranks in importance with Langstroth's discovery of the bee space and invention of the movable-frame, top-opening hive, and with the invention of comb foundation. The invention of the honey extractor is accredited to Major Franz von Hruschka (Fig. 155), an Austrian, in 1865, who discovered the principle of the extractor when he noticed that honey was thrown from the cells of a comb which his son playfully swung around in a basket. Langstroth was the first American to recognize the importance of this discovery and, as early as 1868, constructed an extractor similar to Hruschka's.

Charles Dadant, Moses Quinby, A. I. Root, H. O. Peabody, and others contributed to the early development of the honey extractor. According to Pellett,[2] T. W. Cowan appears to have been the first to build an extractor of the radial type, while Root[3] attributes the building of the first practical radial extractor to Arthur Hodgson.

The invention of the honey extractor and its subsequent development greatly influenced the progress of beekeeping. Methods of separating the honey from the combs by heat, often resulting in discoloration and injury to flavor and aroma of honey, could be abandoned. The combs of honey no longer had to be crushed to obtain strained honey. Furthermore, when the emptied combs were returned to the bees, greater yields of honey were obtained.

As trucks and automobiles became common and radial extractors came into more general use, the advantage of a central extracting plant,

---

*Roy A. Grout. Production manager of Dadant & Sons. Associate editor of the *American Bee Journal.*

[1]Sechrist, E. L. 1937. Honey house and workshop. *Amer. Bee Jour.* 77:121-123.

[2]Pellett, Frank C. 1938. *History of American Beekeeping.* Ames, Iowa. Collegiate Press, Inc. p. 73.

[3]Root, E. R. 1947. *ABC and XYZ of Bee Culture.* Medina, Ohio. A. I. Root Co. p. 264.

FIGURE 155. Major Franz von Hruschka to whom is accredited the discovery of the centrifugal extractor in 1865.

or honey house, became apparent. Here the extracting, storage of honey and equipment, wax rendering, and the workshop could be located under one roof for greater efficiency and with less expense of operation. Again the ingenuity of the beekeeper was applied to create a central honey house which would meet his particular requirements. Thus, today's honey house is the result of the development of the ideas and inventions of many beekeepers, plus improvements and developments made by manufacturers of extracting equipment.

In areas where the summer temperatures are high enough to result in injury to combs if they are hauled to a central extracting plant, beekeepers have resorted to portable extracting outfits (Fig. 156) which extract the honey at the outapiary. Such units are equipped with gasoline motors and steam boilers for operating the extracting equipment. The extracted honey either is pumped into a tank on a separate trailer or into a tank mounted on the same trailer. The portable extracting plant is relatively less expensive than a permanent building. Its use eliminates breakage of combs in hauling and a trip back to the yards with the empty supers. Further, the emptied supers can be returned to the same colonies, minimizing transmission of disease and immediately providing additional storage space for the bees.

## The Honey House

The honey house should be efficiently arranged and of ample size to accommodate the requirements of the beekeeper. A simple structure with the equipment compact and well arranged is better than the finest building with the best equipment poorly arranged. Experience has shown that many beekeepers make an unjustified expenditure in the building and the equipment of a honey house, which later may contribute to a burdensome overhead or even a substantial loss. This has been emphasized in days of relatively low prices for honey and in regions where changes in agriculture have made it necessary to move entire outfits, leaving expensive honey houses behind.

To offset such possibility of loss, some beekeepers have constructed honey houses which are designed as warehouses, having reinforced concrete floors and located on railroad sidings. Others have built bungalow types of buildings which can be converted readily into fine homes.

Honey house fires have taught beekeepers to build as fireproof or fire resistant a building as is economically possible, such as a corrugated iron building with a concrete floor, and to locate the honey house in a community where there is fire and police protection. If the building is a frame structure, it should be set at a sufficient distance to eliminate the possibility of fire in an adjacent building spreading to the honey house.

Insurance should be carried on the honey house and its contents. Locations having fire protection will, of course, have a much lower rate. The type of structure, its arrangement, and the surroundings also will

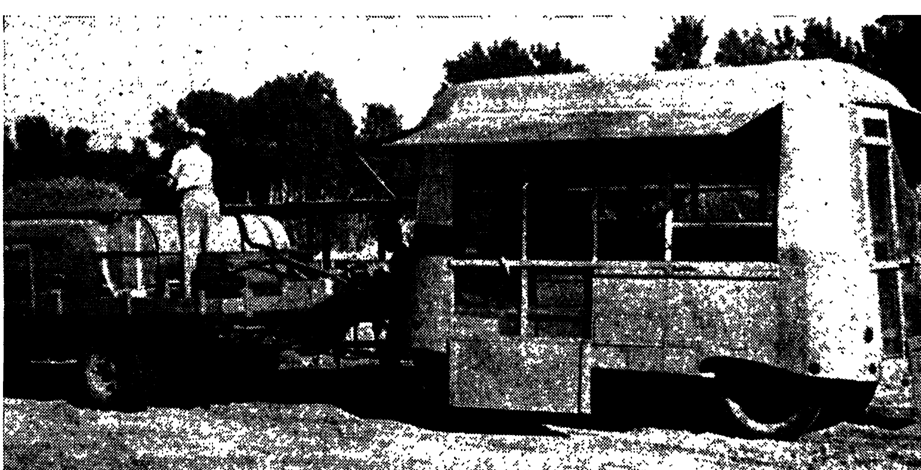


FIGURE 156. The portable extracting plant has a number of advantages, particularly for the honey producer in the Southwest, but most operators in milder climates prefer the central extracting plant. (*Photo by J. E. Eckert*)

influence the premium rate. A fluctuating type of insurance can be obtained with the premium based upon the building and what it contains from time to time. Thus, when the supers are on the bees and most of the equipment is out of the honey house, the premium is reduced.

Labor is a very important consideration in the design, arrangement, and equipment of the honey house. During the extracting period, the large beekeeper usually must depend upon unskilled or inexperienced labor to perform most of the extracting work. The small beekeeper has just as important a problem because he does not depend upon bees for his entire livelihood and often must do his extracting efficiently and quickly. The middle-size beekeeper has an even greater problem, both in the economy with which he must plan his honey house and the selection of suitable equipment.

For some, a co-operative plan of operating a honey house may be a solution. The cost of the building and its equipment, as well as the overhead and operating expenses, can be shared in some way, and those involved can work together to their mutual benefit. Custom work can help solve the problem of others. One of the group may own and operate the extracting equipment, doing the extracting of the honey for a fixed charge, usually at a saving to those involved. Combs can be rendered and sugar sirup for feed can be prepared on a similar basis.

Sechrist has given the following requisites for a good honey house: It should be large enough, but compact and well planned for its particular requirements; the building should be bee tight, well ventilated, and capable of being kept thoroughly clean; the floors should be as nearly perfect as floors can be made and should be strong enough to carry heavy loads and be free from vibrations; and the building should be planned so that the honey, when brought into the building, goes in a continuous

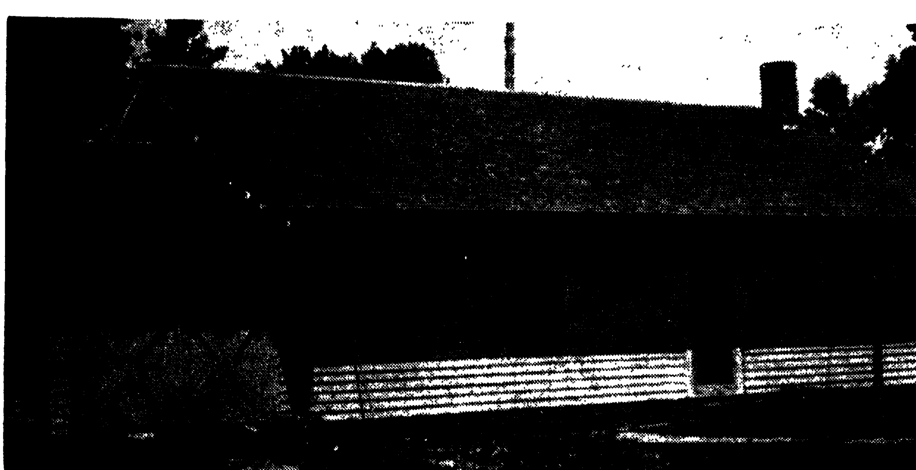


FIGURE 157. A relatively small honey house serves as garage as well as for extracting the honey crop and storage of equipment.

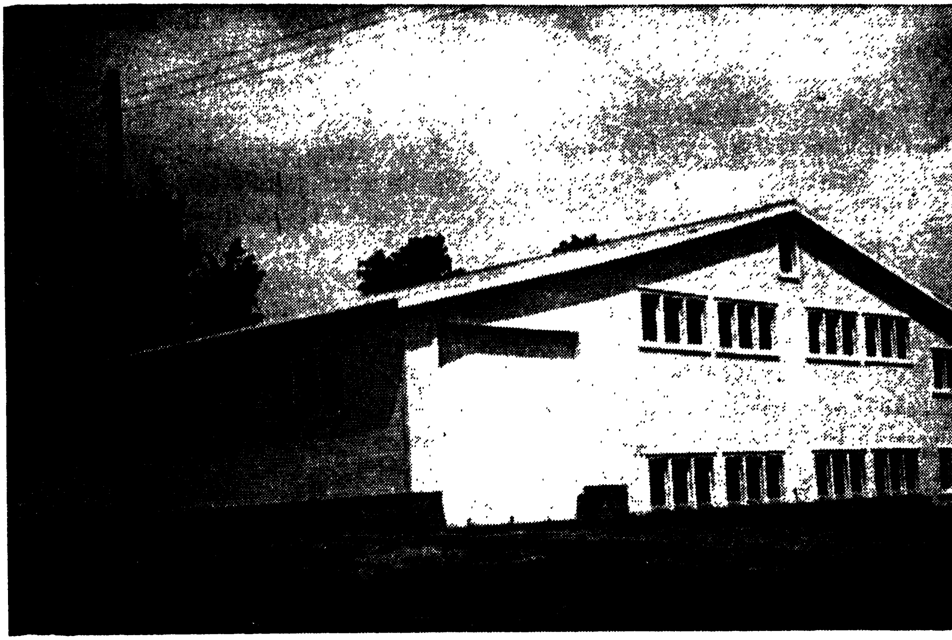


FIGURE 158. A splendid large two-story honey house consists of one floor above the ground level and a full basement underneath, providing for gravity handling of honey. (*Photo courtesy Howard Potter*)

and direct line of travel to the storage tanks and shipping room. To this should be added that the building should be well lighted and its construction should be as fireproof or fire resistant as circumstances will permit.

In all cases, the honey house should have a space for the full supers as they are brought in from the apiary, a place for uncapping the combs and for extracting the honey, a space for the storage of supers of empty combs, room for heating, straining, and clarifying equipment, and a place for the storage of the liquid extracted honey. In many cases, the honey house also serves as the truck garage, although a greater fire risk is involved. Often the steam supply and heating plant are located in the honey house, but many place this equipment in a separate, small building at a sufficient distance to minimize fire hazard. Wax melting and rendering equipment could well be included in the separate building for the same reason.

## TYPES OF HONEY HOUSES

The most common type of honey house is the one-story structure used generally by both large and small beekeepers (Figs. 157, 158). The construction of the building is simple, and it has the advantage of all operations being on the same level, making supervision of work easier. The principal disadvantage is that it is not readily adapted to gravity handling of honey. Probably the most economical structure is the Quon-

set-type, corrugated iron building erected on a concrete foundation and a concrete floor.

The floor of the honey house should be constructed at a level which will permit loading and unloading of trucks at the same level as the bed of the truck. When built on a slope, this is easily arranged, but when constructed on level ground it either is necessary to have the floor of the honey house above the ground at the level of the truck bed, or to lower the driveway in some way.

The two-story honey house may have two stories above the ground or one story above the ground with a full basement underneath. The two-story house constructed on a foundation above the ground presents the difficulty of building a concrete ramp or other kind of driveway to the second floor for loading or unloading of trucks. On sloping ground, the type with a basement underneath is found to be most practical from all standpoints. When built on level ground, this type of honey house presents the problem of a depressed driveway into the basement and a consequent drainage problem.

In the two-story honey house, the supers of honey can be unloaded at the upper level where the extracting plant is located. Here the honey is extracted and flows by gravity to the storage tanks below. However, with modern honey pumps and honey handling equipment, the extracting of honey can be accomplished as readily in the one-story honey house. Both types are adaptable to the ideal system of handling honey in which from the time the trucks drive in with the supers heavy with honey until they drive away with the extracted honey, no unnecessary manual lifting need be done.

## Construction Features

Foundations and footings should be deep enough to prevent upheaval by frost, usually about 3 feet (Fig. 159). They should be constructed of good concrete, stone, or brick. Hollow tile is not sufficiently strong and should be surrounded with a sufficient thickness of concrete to strengthen

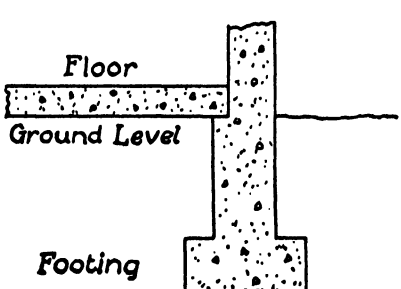



Figure 159. Diagram of the foundation and footing—necessary in the proper construction of any building.

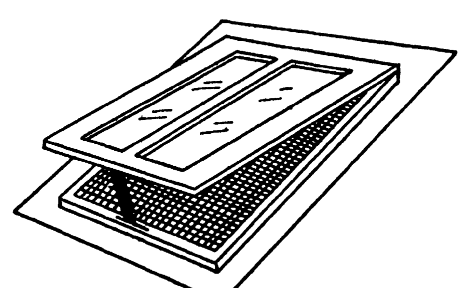


Figure 160. Roof windows are not hidden by stacks of equipment, provide more light, and can be opened for ventilation.

and keep out moisture, if used. Footings should extend beyond the width of the foundation wall on each side, being approximately twice as wide as the wall, and should be as deep as the wall is wide. If concrete is used, a mixture of 1 part cement, 2 parts sand, and 4 parts gravel, properly mixed and handled, will make an impermeable concrete.

Below the surface of the ground, it is desirable that walls and floors be of concrete. The 1-2-4 mixture will be suitable if the concrete is well mixed and puddled. The walls or floors should be completely poured at one time or water eventually will seep through where stops are made in pouring. It is well to remember that concrete is only as good as the workmanship in preparing and forming it. To obtain a floor surface which is smooth and will stand heavy wear, concrete should be mixed in the proportion of 1 part cement to 2 parts sand, and well troweled over the surface. Plenty of slope toward each drain should be allowed to permit quick exit for water when the floors are flushed or scrubbed.

When not possible to have concrete floors, a well-laid, hardwood floor is recommended. The sills of the building should be 18 inches above the ground to prevent termite damage and to aid in the control of ants. Waterproof paper should be placed between the subfloor and the hardwood flooring, and the joints of the flooring should be waterproofed in some manner as the flooring is laid. Afterward, the floor should be well oiled or painted. In general, honey house floors should be of a kind that can be kept clean easily, will stay smooth under cleaning and trucking, and should be strong enough to carry heavy loads and minimize vibration of machinery.

The walls and ceiling of the extracting plant should be of a type that can be kept spotlessly clean. If of wood, tongue-and-groove or shiplap siding should be used, and the walls should be well painted to stand repeated washings. Since honey must be extracted and otherwise handled in contact with air, as much care should be taken to produce a clean, wholesome product as with any other food.

Lighting and ventilation should be given careful consideration in the planning of the honey house. To a certain extent, electric lights must furnish lighting, so the building should be wired in a manner that will pass the inspection of fire insurance companies. But the main source of light, as well as ventilation, is the windows. Good lighting from windows is desirable in all parts of the honey house, and consideration should be given to a sufficient number of windows placed high in order to give the maximum amount of light and ventilation. Particularly in the one-story building, where stacks of supers and other equipment often hide the light, consideration should be given to the roof window (Fig. 160). The roof window is claimed to give 35 per cent more light and can be opened for ventilation.

The roof of the honey house should be gabled high to form a loft in which light equipment may be stored. A steep roof is easier to main-

tain, and is less likely to leak because water gets away quickly. A fire-resistant type of roofing always should be used.

Above all, the honey house should be bee tight. It is desirable for trucks to be driven inside the honey house and doors closed to prevent the troublesome presence of robber bees. This portion of the honey house could well be screened from the extracting area. The presence of bees in the honey house will result in their getting into extracting equipment, as well as staining the windows and wall surfaces. If necessary, sprays should be used to kill those bees which find entrance. All openings needed for entrance, light, or ventilation should be screened and equipped with escapes to allow exit for bees. Nothing will make the extracting task more annoying to inexperienced help, or the honey house more unsightly to the customer, than the presence of bees in the honey house.

## The Steam Supply

If steam is required only for heating one or two uncapping knives or planes, the 1- or 2-gallon copper steam generator heated by a one-burner oil or gas stove will be sufficient. But when steam is required for heating the honey or melting the cappings, in addition to heating the uncapping equipment, a larger source of steam supply will be needed. Many will find the 8-gallon steam generator large enough, but large beekeepers will find a steam boiler necessary.

A boiler of about 5 horsepower capacity will supply steam for warming the combs, for heating the uncapping knives, for heating honey, for melting the cappings, for rendering beeswax, and even for heating the honey house. Very large operators may find it advisable to install a boiler having a capacity of 10 horsepower. The flueless type of boiler is preferred because there are no flues to replace later at considerable bother and expense.

The steam gauge and water-level glass should be placed where they can be seen at all times. Most boilers are hand-fired, the only objection being the attention required in operating them. Some should consider the use of an automatically controlled oil burner which is cleaner and requires much less attention. Consideration also should be given to the type of boiler having an automatic steam control and automatic water injector which maintains a proper water level in the boiler. This type of boiler is available in sizes of 5 horsepower and larger.

## Care and Storage of Supers of Honey

In handling the supers of honey, the use of the single hauling board or tray is a great aid in making the extracting work easier and in preventing honey from dripping on the floors (Fig. 161). These boards are

FIGURE 161. This stack of supers is resting on a hauling board. The extensions on the bottom of the hand truck slip under the hauling board.

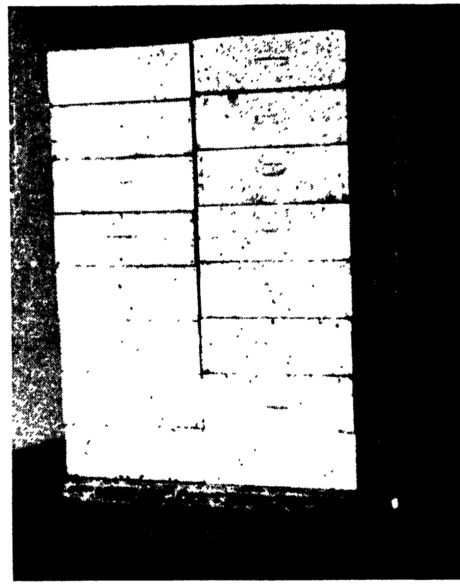


FIGURE 162. This platform holds two stacks of supers, and can be moved about the honey house readily by means of a hydraulic lift truck.

usually the size of the bottom of the super, often cleated all around with a ½- to 1-inch cleat, and with two heavier cleats nailed lengthwise underneath. Sometimes they are covered with a galvanized iron tray which can be removed easily for washing and cleaning. They can be placed on the truck bed and supers piled on them as they are removed from the colonies. When unloading at the honey house, an ordinary warehouse truck with an extension on its front can be shoved under each stack of supers for wheeling to any part of the honey house. After extracting, the supers are placed on hauling boards for further handling. They also can be used to cover stacks of supers.

Large operators sometimes use the more expensive lift trucks capable of handling skids or platforms holding two, four, or six stacks of supers (Fig. 162). Like the hauling board, the skid can be covered with a galvanized iron tray to catch the dripping honey. A departure from the single hauling board is the dolly, a low platform holding one or two stacks of supers, supported by three or four casters enabling them to be rolled about the honey house. The dolly only works well on smooth floors and is not suited for trucking from the yards. A departure from the dolly is the platform truck having two large wheels in the rear with a strong stationary support in front. A jack mounted on rollers is inserted under the front to raise it for moving about the honey house. The most economical and practical of these methods is the single hauling

board, but the requirements of each beekeeper will dictate which is best for his use.

When none of these methods are in use, supers of honey should be set on clean paper, whether in the wheelbarrow, on the truck, or in the honey house. The papers can be gathered up and burned, and will save much scrubbing and cleaning. A number of pans about 4 to 6 inches deep and large enough to contain a stack of supers are useful. Sometimes accidents occur; a super is dropped or a stack of supers is upset. If these supers are placed in the pans, much cleaning can be eliminated and the honey which drains from the broken combs can be saved.

Usually the honey is extracted from the combs soon after they are brought into the honey house. The average beekeeper has comparatively few colonies and economy dictates that the supers be placed in or near the extracting space. In cool weather, when it is necessary to warm the honey in the combs, it also is necessary to heat the extracting area.

In regions where the humidity is high or where honey is thick and cold, a heated room for storage of supers of honey is desirable. The room should be large enough to accommodate as many supers as are brought in during several days' work. The supers are stacked criss-cross or alternately spaced to permit circulation of warm dry air through them. The temperature of the room should not exceed 100° F. and a sufficient time should be allowed for the combs to warm gradually. Higher temperatures will soften the wax of the combs, causing damage to them in the extractor. The combs of honey should not be left in the warming room for more than 2 or 3 days at temperatures above 70° because higher temperatures will result in discoloration of the honey. It is advisable to circulate the air in the room with a fan to prevent the top supers from becoming too warm while those near the floor may be cool.

When supers of honeycombs are stored for more than a week before extracting, it is necessary to fumigate to prevent damage by the larvae of the wax moth. For methods of fumigation, see Chapter XXIII, "Diseases and Enemies of the Honey Bee." Whenever practical, supers of honey from different plant sources should be kept separate and extracted separately. This will prevent dark-colored or strong-flavored honeys from mixing with light-colored or mild-flavored honeys, resulting in honey of an inferior quality which receives a lower price in a normal market. Sometimes honeys are mixed in the supers and it is impossible to separate them. This may be due to the neglect of the beekeeper in not removing supers of one kind of honey and adding other supers before another kind of nectar is gathered, but there are conditions when this is unavoidable.

## Treatment of Cappings

To extract the honey from the combs, it is necessary to cut away the cappings from the surface of the comb. A warm comb can be uncapped

with a sharp, cold knife such as T. F. Bingham invented. A knife of this kind, when heated by placing it in hot water, can be used when the combs are not warm. In 1912, the A. G. Woodman Company, Grand Rapids, Michigan, purchased Bingham's uncapping knife and bee smoker business. It was after this that the steam-heated uncapping knife was developed. Later the steam- and electrical-heated uncapping plane and the electrical-heated knife were introduced. The power-driven, steam-heated uncapping machine has been used for some time, and beekeepers have developed other ingenious ways of uncapping the combs with power-driven equipment. All of these uncapping devices are used, depending upon which the beekeeper prefers or finds best adapted to his circumstances.

The inexperienced operator usually will do a better job and uncap more combs with a power uncapping machine than with the heated knife or plane. But the experienced operator can uncap as many combs with a heated knife as he can with most power uncapping machines. In fact commercial beekeepers consider the uncapping of combs with our present equipment a bottleneck in extracted honey production.

The uncapping of the combs is performed over a receptacle into which fall the cappings. The next step is to separate the honey, which is removed with the cappings, without injury to its color, flavor, or aroma. Two methods are in general use: (1) Draining by gravity, centrifugal force, or pressure, and (2) melting the cappings so that the liquid wax will separate from the honey and rise to the surface. Frequently a combination of the two methods is used. A few beekeepers have ingenious ways of using the bees to clean the honey from the cappings after they have been drained.

An earlier method, although still used today, is to allow the cappings to fall into an uncapping can. This usually is a tall container with a screen midway to catch and hold the cappings, or it may consist of two tub-shaped containers, the upper one having a screened bottom. The cappings are stirred and broken up with a wood paddle to facilitate draining of the honey into the bottom container. Other operators use long shallow boxes or tanks large enough to hold at least a day's cappings. In all cases, the cappings should be allowed to drain for at least 24 hours before further treatment. The honey obtained is not injured in any way and can be added to the balance of the crop.

When cappings are drained by centrifugal force, the beekeeper either may uncap into some device similar to those mentioned previously and the cappings transferred later to the centrifugal drier, or he may uncap into baskets constructed so that they fit into the drier. The honey extractor often is used in this way for drying the cappings. Some operators use a specially constructed centrifugal drier and uncap into it while it is running (Fig. 163). At the end of the drying operation, the cappings are removed and placed in storage until further treatment.

When cappings are drained by pressure, they first are allowed to fall into a container from which a part of the honey drains by gravity before the pressing operation. Usually the basket-shaped container consists of wood strips bound with metal hoops, which later is set under the screw of the press. A small press, similar to a cider press, is used with a follower board under the jack screw. Some have used heavy automobile springs between the follower board and the jack screw, permitting the springs to be compressed when pressure is applied by the screw and continuing the pressure for a long time. When removed, the cappings are in the form of a cheese which can be stored for melting later on. The compressed cappings frequently contain as much as 50 per cent of honey by weight. Cappings that have been well stirred and drained by gravity over a screen in a warm place for a sufficient time contain no more honey than cappings that have been dried by centrifugal force or by pressure.

Cappings melters function in two ways: (1) To melt the cappings after the excess honey has drained from them, and (2) to melt the cappings and separate the honey from the beeswax at the time the combs are uncapped.

Drained cappings are either melted over an excess of hot water or in a steam-heated melting device. One cappings melter for handling drained cappings is marketed. Similar in construction to many devices contrived by beekeepers, it consists of a series of steam-heated vanes or coils for melting the cappings. The melted beeswax and honey run down between

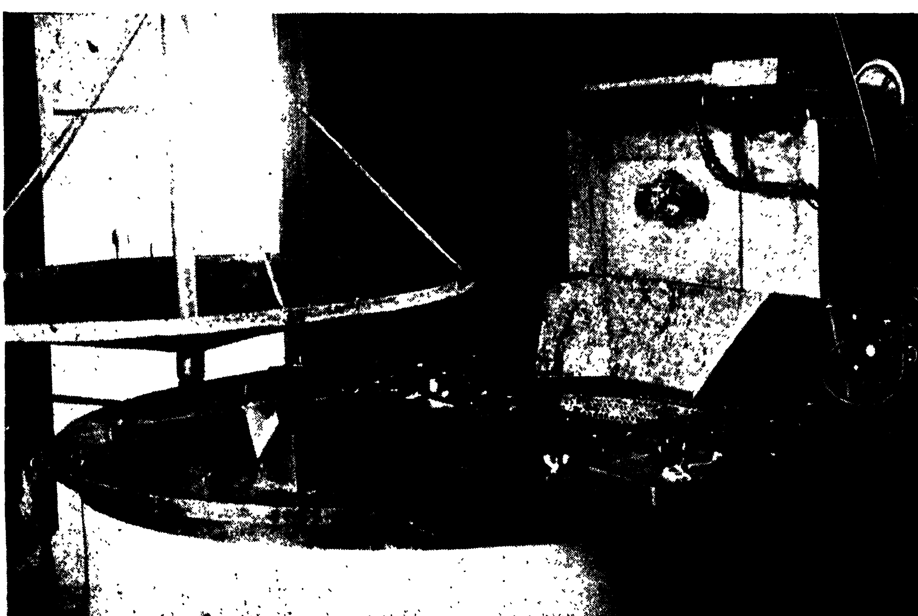


FIGURE 163. In center foreground is a centrifugal cappings drier into which the cappings fall from the power uncapping machine at right.

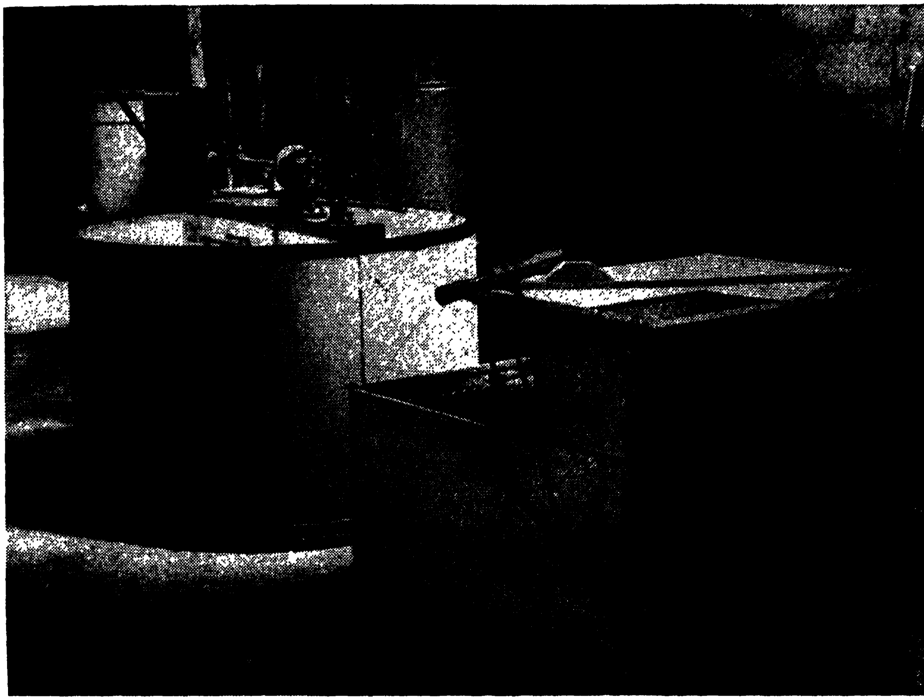


FIGURE 164. The Brand cappings melter, an outstanding development in American beekeeping, separates the beeswax and honey from the cappings in one operation. The extracting equipment includes a 50-frame radial extractor.

the vanes and separate and run into different containers. The honey usually is discolored and the flavor and aroma is injured, and should not be added to the remainder of the crop. Particularly in the South, the solar wax extractor is used for melting drained cappings. In warm climates, it works very well for melting the cappings but results in injury to the color, flavor, and aroma of the honey. For further information concerning the melting of cappings, see Chapter XX, "Production and Uses of Beeswax."

The first melter used generally to melt the cappings as they fell from the knife was the Peterson cappings melter. Root[4] describes a similar melter having a small steam coil at one end upon which the cappings fall. In both, the sloping surface of the bottom of the melter is jacketed with hot water to melt the cappings and to heat the honey. The honey and the liquid wax run out at the lower end into a separating can. This type of melter overheats the honey, and soon becomes coated with a certain amount of slumgum with which the honey comes into contact, resulting in honey unsuitable for adding to the remainder of the crop or for marketing as honey of good quality.

[4]Root, E. R. 1947. *ABC and XYZ of Bee Culture*. Medina, Ohio. A. I Root Co. p. 256.

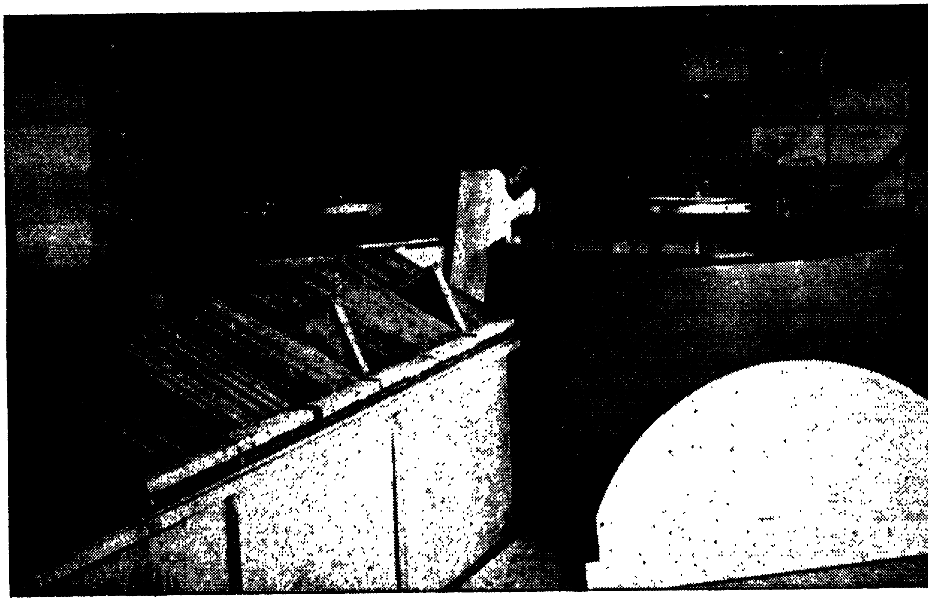


FIGURE 165. Uncapped combs draining in a rack over a tank which also catches the cappings as they fall from the uncapping device. The next task is to put them into the large radial extractor.

The Brand cappings melter employs the principle of floating the cappings on the surface of the honey removed with them until they touch a steam-heated melting unit suspended above them, where they gradually melt (Fig. 164). The combs are uncapped into a hopper at one end of the melter, the cappings and honey falling on a sloping surface and sliding underneath the melting unit. The melting unit does not come in contact with the honey, which is only moderately heated and separates from the wax and slumgum. As the liquid wax collects at the level of the melting unit, it is run off into molds. The honey level is maintained several inches below the heating grid, and the excess honey overflows during the operation. The melting unit can be raised for cleaning and the slumgum can be skimmed off the top from time to time. If properly operated, the honey will be affected only slightly in color and flavor and may be added to the rest of the crop without injury to its grade. At the end of the workday, the beeswax is in the form of a cake suitable for marketing, and the problem of storing the cappings and later melting them is eliminated. The principle of the Brand cappings melter is an outstanding development in American beekeeping.

## Extracting the Honey

After the combs are uncapped, they usually are placed in some device which catches the honey that drips from them until they are put into

the extractor. A few may find it practical to uncap their combs and place them directly into the extractor where the honey is removed from the combs before more are uncapped. Some have used two extractors, filling one while the other is in operation. However, most will find that it is desirable to have some device for holding the uncapped combs.

When a large uncapping box or tank is used into which the cappings fall for draining, the combs often are set in a rack above the cappings until placed in the extractor (Fig. 165). Many use a comb rack which is set conveniently between the uncapping device and the extractor, sometimes mounted on casters. The revolving rack, called the Merry-Go-Round, is an ideal piece of equipment when the radial extractor is used (Fig. 166). It consists of a round comb rack, revolving above a stationary pan which slopes to the center. The honey which drains from the combs is caught by the pan which is connected with the extractor or the honey sump. It provides for racking 50 combs in five numbered segments, making it possible for the beekeeper to return the same combs, when empty, to the supers from which they were removed.

## The Honey Extractor

The small beekeeper has a choice of the basket-type extractor in which the combs are reversed by hand (Fig. 167), and the reversible-type in which the baskets swing to reverse the combs. Both types are made in

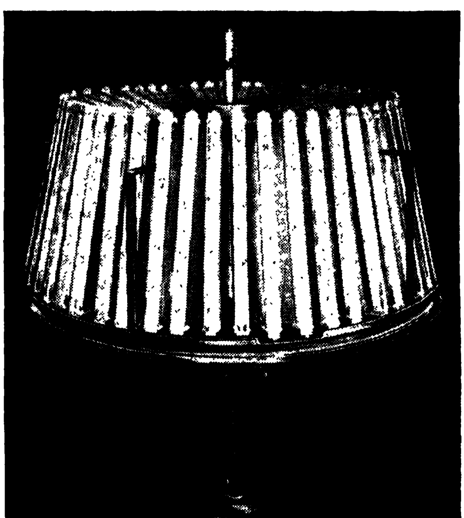


Figure 166. The Merry-Go-Round, a radial comb-draining rack for holding the uncapped combs until they are extracted. (*Photo courtesy A. G. Woodman Co.*)

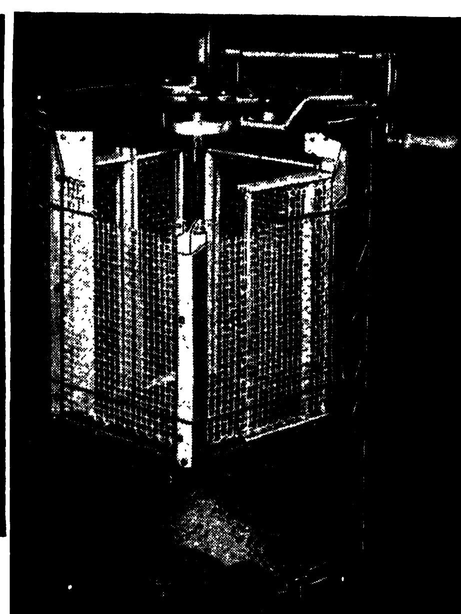


Figure 167. This small extractor holds four large combs or eight shallow combs, and harvests the crop for the small beekeeper. (*Photo courtesy A. G. Woodman Co.*)

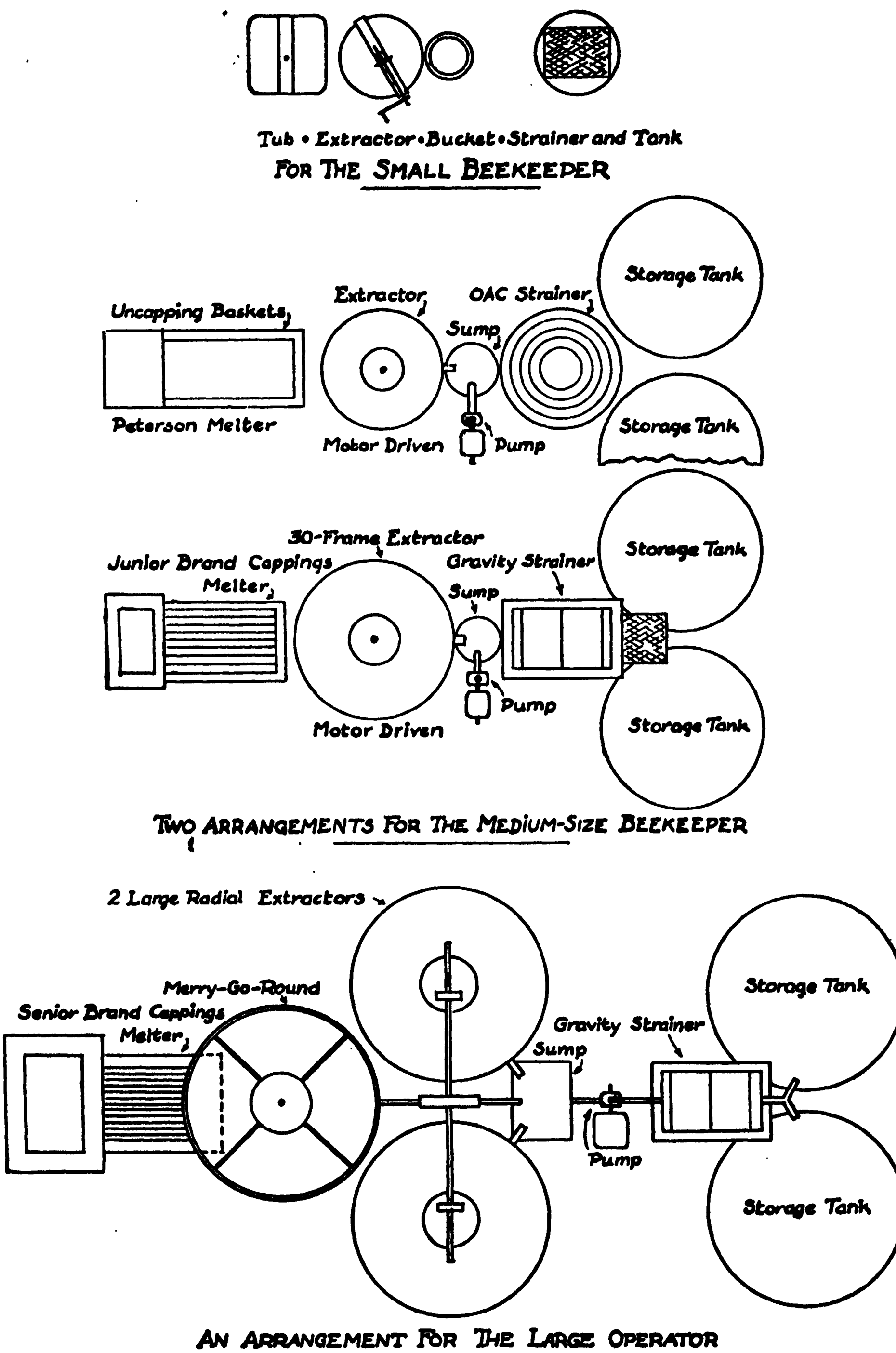



FIGURE 168. Diagram showing extracting arrangements for various sizes of beekeeping outfits.

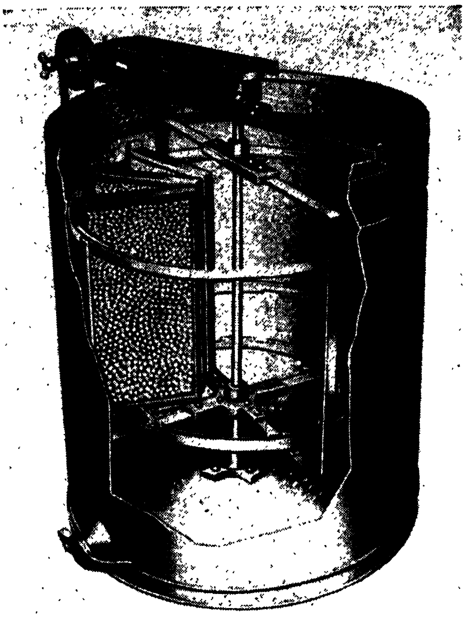


FIGURE 169. A 12-frame radial extractor—now available to meet the requirements of the medium-sized honey producer. (*Photo courtesy Standard Churn Co.*)

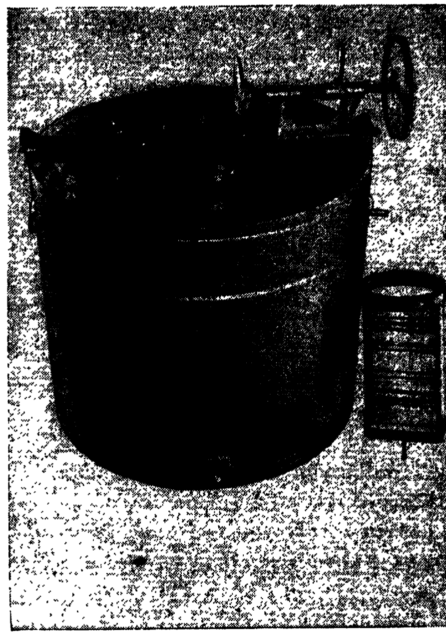


FIGURE 170. The pivotal-reversible extractor holds eight combs, the baskets turning to reverse the combs during the extracting. (*Photo courtesy Superior Honey Co.*)

either a two-frame or four-frame size. Time, labor, and other circumstances will dictate whether less expensive equipment of this kind should be used, or whether the radial or pivotal-reversible extractor should be used (Fig. 168). It is reported that the four-frame extractors are capable of handling 1,000 pounds of honey each day when operated by one man. In one of the Dadant apiaries with four men working under ideal conditions, 5,500 pounds of honey were removed from the hives and extracted in a single 10-hour day with a nonreversible, four-frame, basket-type extractor turned by hand.

In the central extracting plants of today, the radial extractors and other power-driven types are generally used. The radial extractor is built in 12-, 30-, 45-, and 50-frame sizes (Figs. 164, 169). The machines are strong and durable, standing up under many years of service. Depending upon the temperature and the density of the honey, the time required to extract a loading of combs is from 15 to 30 minutes, with the average time about 20 minutes. The larger sizes will extract from 5,000 to 7,000 pounds of honey in a day. The shaft speed should be about 300 revolutions per minute for the smaller sizes and about 275 for the larger sizes. The friction drive allows for gradually increasing the speed of the reel until it is turning at approximately the same speed as the drive shaft. Difficulty is sometimes experienced in breakage of new combs, particularly

when they are warm, so care should be taken when starting the extractor to increase the speed of the reel gradually. Much of this kind of trouble has been eliminated by the introduction of the Rosedale winged comb supports which firmly clasp each side of the comb in the extractor, thus minimizing breakage.

The pivotal-reversible extractor is preferred by some to the radial, and when power-driven is usually obtained in the 8-frame size (Fig. 170). The combs are contained in baskets which automatically reverse while the machine is running, and results in little or no breakage, regardless of how cold or thick the honey may be. It is claimed that this type of equipment will extract honey as fast as the radial, particularly when the honey is heavy in body.

### Pumping the Honey

From the extractor the honey flows directly into a honey sump where the coarser foreign materials are removed. The sump is a reservoir for containing the honey while it is being pumped or before it flows by gravity through the heating and straining processes. Honey drained from the cappings and from the uncapped combs may be introduced at this point. Usually the sump is provided with a coarse wire-mesh basket or screen to catch particles of beeswax and large foreign materials. Hardware cloth having ¼- to ½-inch meshes should be used for this purpose. In addition to the coarse screen, some sumps have one baffle plate, extending from above the surface of the honey to a point near the bottom, under which the honey flows before leaving the sump. The purpose of the baffle plate is to separate the lighter foreign materials from the honey.

When the extracting plant is on the same level as the tank storage space, it usually is necessary to use a honey pump. The honey pump should be suitable for handling viscous materials, should be geared to run slowly, and should have large inlets and outlets. Suitable types are marketed by manufacturers of honey house equipment. The honey pump should remove the honey from the sump or reservoir, but should not be allowed to run until the pump sucks air. A float attached to an automatic switch, which turns the pump on when the honey level reaches a fixed height and off when a low level has been reached, is a timesaver to the beekeeper and eliminates the mixing of air with honey. Available on the market is a combined honey pump and reservoir tank with automatic controls of this kind.

When the honey pump is not of the right kind or is operated carelessly, air is incorporated into the honey. The air bubbles that rise in the straining and settling equipment cause a foam on the top of the honey, troublesome to handle. Smaller air bubbles remain in the body of the honey, along with small particles of suspended wax and other foreign material, causing a permanent cloudiness. The pipe lines which carry the honey from the pump to the straining and settling equipment should

be large (from 1½ to 3 inches in diameter) to avoid excessive friction. Even when the honey pump is operated properly, air will be incorporated into the honey if resistance in the pipe lines is too great.

## Heating, Straining, and Cooling Honey

Sechrist[5] has said that honey should never be heated unless it is absolutely necessary, and that then it should be heated only as much as is necessary to give the desired results; that it should be heated quickly and cooled again as soon as possible. Phillips[6] and others have favored methods which avoided heating of honey in the extracting process, at least until impurities had been removed. Phillips also has pointed out that there is a marked variation in honeys with respect to the amount of heating which they can stand without noticeable damage. Most mild-flavored and light-colored honeys may be heated to a higher temperature for a longer period without change than can the dark honeys and those with pronounced flavors.

W. G. le Maistre,[7] of Canada, stated that honey should be strained at 70° to 90° F. because heating honey that contains foreign particles darkens it and impairs its flavor. As a result, the Ontario Agricultural College developed the O. A. C. honey strainer (Fig. 171). It is recommended that the honey, coming from the extractor without any heating, flow into a tank with a baffle plate in it before going into the strainer. The strainer consists of a tank containing a series of round screens, 12, 30, 50, and 80 meshes to the inch, through which the honey flows in the order mentioned before flowing under the baffle and out of the outlet. When honey is not too thick or too cold, this strainer works well.

However, most beekeepers find it advisable to heat honey to facilitate its handling after being extracted. Most honeys, especially if cold or of heavy body, do not strain readily or settle and clarify easily. For these purposes, it is not necessary to heat honey beyond 90° to 100° F. To prevent or to retard granulation and fermentation, it is necessary to heat honey to higher temperatures but this should not be done until after the honey has been strained.

To prevent granulation, it is necessary to melt any granules of honey which may have become mixed with the liquid honey due to granulated honey in the combs or in the honey-handling equipment. Milum (see Chapter XV) has indicated that dextrose crystals float in the air, and that seeding of liquid honey with them induces granulation.

According to Milum,[8] the most common recommendation for heating honey to prevent granulation is to heat the honey in a water bath with

---

[5]Sechrist, E. L. 1938. Other equipment in the honey house. *Amer. Bee Jour.* 78:216–218.
[6]Phillips, E. F. 1939. The effects of heating honey. *Gleanings in Bee Culture* 67:146–148.
[7]le Maistre, W. G. 1937. O. A. C. honey strainer. *Amer. Bee Jour.* 77:14–15.
[8]Milum, V. G. 1939. Granulation and its prevention. *Amer. Bee Jour.* 79:348–351.

some means of gentle agitation until the honey reaches 160° F. and to hold it at that point for 30 minutes. It then should be cooled as quickly as possible. If beekeepers do not have equipment suitable for accomplishing quick heating and cooling, most honeys that are heated to this extent will be injured in quality.

Heating honeys to 145° F. for 30 minutes has been found sufficient to kill the yeasts and to prevent fermentation, but not granulation. The honey should be drawn into containers, sealed while hot, and the containers set apart for cooling. Many honeys will ferment when placed in warm storage unless so treated.

Heating honey also tends to keep the moisture content low, which is an aid in the prevention of fermentation. This is desirable with honeys produced in areas where the humidity is high or where the flow comes so late that the bees often do not have opportunity to ripen the honey thoroughly. It likewise is true with honeys that have been removed from

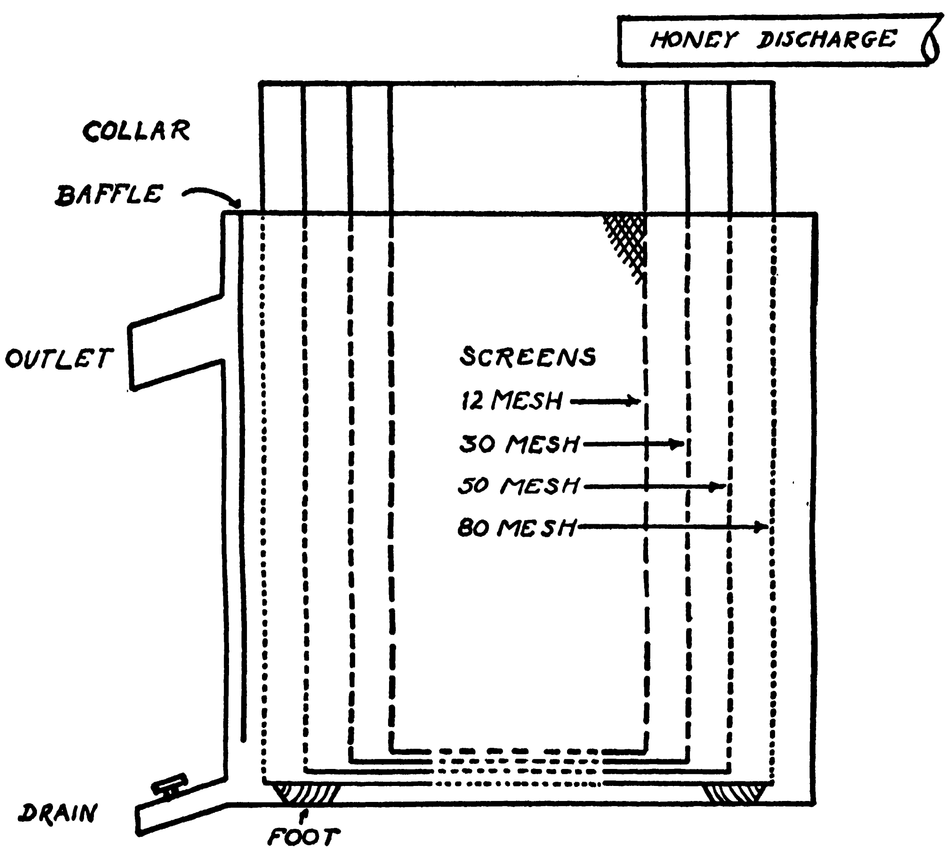



FIGURE 171. Diagram of the O.A.C. honey strainer, designed for handling honey without gravity separation or heating.

the hives before being fully ripened, and with honeys in combs that have been stored in a damp place.

Probably the ideal way to heat most honey is to bring the temperature, after extracting, to 90° to 100° F. to facilitate straining, settling, and clarifying. Then to heat the clean honey quickly to 145° or to 160° for 30 minutes, draw into containers, seal while hot, and set apart for quick cooling.

### Methods of Heating Honey

A simple way of heating honey is to allow it to run quickly down the inclined surface of a shallow pan. The pan should be about 2 inches deep, 2 feet wide, and 4 or more feet in length, and should be jacketed on the bottom to contain hot water. It may be heated from beneath by a gas or oil stove, or by steam. As the honey flows into one end of the pan, some means for spreading it out over the surface, such as corrugations or baffles, is desirable (Fig. 172). A thermometer at the lower end enables the beekeeper to tell the temperature of the honey after passing over the heating surface. This arrangement is simple, economical, and effective if properly done.

Another simple and effective method of heating honey is performed in conjunction with a gravity separator (Fig. 172). The honey flows from the pipe line into a jacketed tank, baffled in the manner illustrated. The water in the outer tank is heated by a steam coil in the bottom. The honey flows quickly under one baffle and over another, and overflows out of the other end of the separator. The temperature of the honey leaving the separator is determined by the speed at which it flows and the temperature of the water jacket. This heating separator accomplishes the task of gravity separation while heating the honey.

Flash-heating, as it is commonly considered today, consists of causing honey to flow quickly through a coil contained in a hot-water bath (Fig. 172). The success of the operation depends on the rate at which honey flows continuously through the coil and the temperature of the hot water surrounding the coil. It has, as do all other methods of heating honey, the objection of overheating some honey when the flow stops or decreases before the temperature of the heating surface is reduced. Milum has pointed out that, although heating honey to 160° F. and even higher for a short period may cause little damage and usually prevents granulation for some time, flash-heating is not always effective with honeys that are heavily seeded with crystals of granulated honey. For a "flash" method to work successfully, it is best that the honey be extracted soon after removal from the bees and processed before granulation occurs.

### Straining and Clarifying Honey

The gravity separator allows the lighter foreign particles to rise to the surface where they may be removed, while the heavier particles are al-

lowed to settle. This sometimes is accomplished in a tank containing one baffle, the heated honey entering at one side, flowing under the baffle, and overflowing out of the top of the opposite side. Sometimes a series of baffles is used, as in the case of the heating separator. Others have used a series of tanks, the honey flowing from a point near the bottom of one through large piping to the top of the next tank. A few have connected large storage tanks together in this manner, having a sufficient number of them to accomplish both separation and settling.

Before the honey enters the settling tanks, it is run through some type of strainer to clean it further. To conform with the requirements of U. S. Grade A, honey must be as clean as though it had passed through standard bolting cloth of 86 meshes to the inch at a temperature of not more than 130° F., and for U. S. Grade B, as clean as though it had passed through bolting cloth of 23 meshes to the inch. For further information concerning grade requirements, see Chapter XVI, "Marketing the Honey Crop."

A common method of straining is through a cloth supported by the top of the settling tank. For straining cold honeys, cheesecloth of several

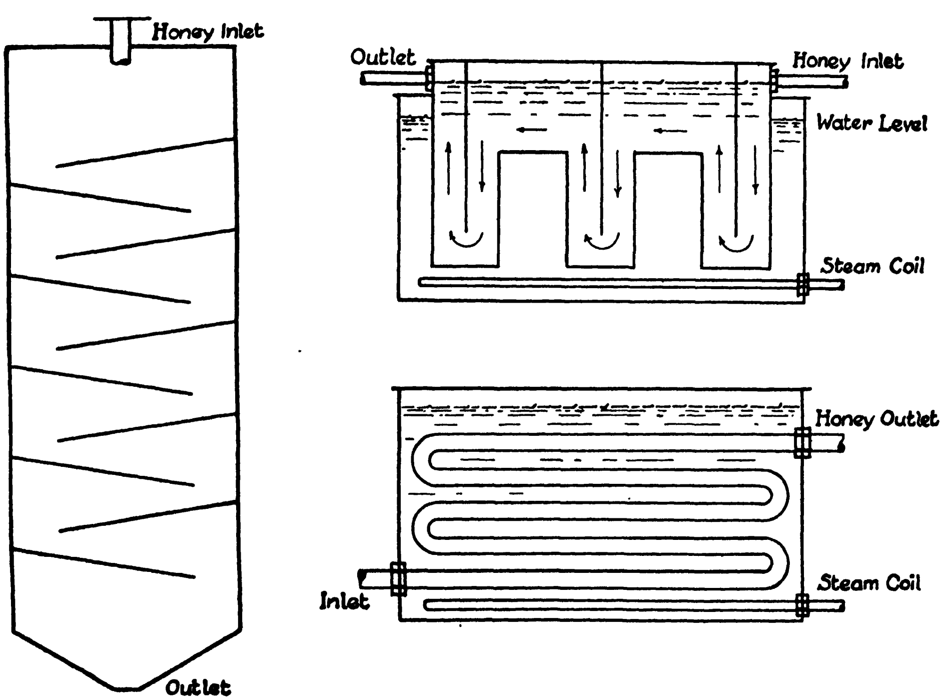



FIGURE 172. Diagram of methods of heating extracted honey. At left, heating honey while it flows by gravity down the baffled course of a shallow pan. At top right, heating honey and gravity separation combined in one efficient piece of equipment. At lower right, heating honey in a coil immersed in a bath of hot water, a common method of "flash heating."

thicknesses is often used. For straining warmed honeys, sugar-sack toweling, muslin, and other materials having sufficient nap to the threads are suitable. Some prefer to use bolting cloth and others prefer metal screen of a fine mesh.

Many use a bag-type strainer made by sewing the full width of a material to form a bag, often as long as the depth of the tank in which it is suspended. The mouth of the bag may be attached to the pipe from which the heated honey flows. As the bag fills, the honey strains through it and gently flows down the sides. The bag-type strainer should be large enough to take care of a day's extracting without replacing or cleaning. At the end of the day, it can be raised above the level of the honey for draining, and is replaced by a clean bag the following day.

The box-type strainer is usually about the size of a hive body, and contains a number of vertical screens through which the honey passes before overflowing at the opposite end. The screens fit into slots in the sides of the box and are removable for cleaning or replacing. Several other types of strainers are used. A multiple basket filter is marketed in which the honey filters through replaceable bags contained in the baskets. Sechrist[9], in his series of articles on honey handling, mentions both a hot-water jacketed strainer and a centrifugal strainer.

To prevent incorporation of air, the honey should not fall from a height into the settling tank. This can be accomplished by allowing the honey to fall on a float, where it disperses in all directions, or by causing the honey to flow down an inclined plane to the bottom of the tank.

When air is incorporated in the honey due to the pump, pipe lines, or other causes, the larger air bubbles rise to the surface in the settling tank and create a foam. The lighter impurities which pass through the straining equipment also rise to the surface as the honey clarifies and become incorporated with the foam layer. An efficient method of removing this layer is to spread a damp cloth gently over the top of the layer, and then to roll the cloth carefully across the top, the foam layer being picked up in the process.

After straining, the warm honey should be allowed to stand in the settling tank until it is clear. A good plan is to have two settling tanks, extracting into one while the other is settling and clarifying. The tanks should be covered at all times to keep the honey clean. While it is a common practice to let the honey settle overnight and to draw it into containers the next day, this is apt to result in injury to the color, flavor, and aroma of some honeys. The honey should be drawn into the 60-pound containers, sealed while hot, and the containers set apart for cooling as quickly as possible. If the honey is to be put into retail packages, they should not be put into the shipping cases until the honey has cooled to room temperature.

---

[9]Sechrist, E. L. 1938. Straining, settling, and clarifying honey. *Amer. Bee Jour.* **78**:216–218.

### Cooling the Honey

Seldom are sufficient precautions taken to cool the honey after heating. Other than allowing the honey to run down an inclined plane into the settling tank, or to set apart the containers of honey, little is ever done. Honey could be cooled by running it through a series of coils in a bath of cold water. Or it could be run down inclined surfaces over corrugations or baffles and cooled by air, or cold water could be circulated through the equipment to speed the operation. If this were done, precautions would have to be taken to prevent the seeding of the cooled honey with dextrose crystals which would induce granulation and the adding of yeasts which later might cause fermentation. However, cooling would prevent the damage to color, flavor, and aroma which results when honeys are held at high temperatures for a long time.

## Care and Storage of Empty Supers

When the empty combs are taken from the extractor, they are returned to the supers. The supers then either are taken to the permanent storage place in the honey house, or to a place near the truck driveway if they will be needed soon.

The permanent storage space for empty supers should be large enough to contain at least four supers for each colony operated. Compared to the extracting area or other parts of the honey house, it should be much larger. Wherever the wax moth is a problem, it is necessary to fumigate the stored combs from time to time to prevent damage by the larvae of the greater wax moth. Thus, the empty-super storage space should be suitable for the proper fumigation of combs, and should be mouseproof and bee tight. For information concerning fumigation for wax moth, see Chapter XXIII, "Diseases and Enemies of the Honey Bee."

Many beekeepers prefer to return the wet supers to the bees to clean or dry them of adhering honey. Drying the combs eliminates the probability of the remaining honey granulating in the combs where it either is wasted by the bees the following season or is extracted with the next season's crop, inducing granulation more readily. When dry supers are returned to the colonies, the bees are not incited to robbing to the extent that occurs when wet supers are taken into the yards. When disease is prevalent, it is advisable to return the supers and combs to the same colonies from which they were taken. Because of the effort and attention required in handling the super combs so that they are returned to the same colonies, some beekeepers stack their supers high over a few colonies, or have arrangements whereby a single colony has access to a number of stacks of supers. In both of these methods, the possibility of spreading disease is present. The best plan is to return the supers to the colonies from which they were removed.

## Care and Storage of Honey

When the honey is not packaged in retail containers and sold soon after, it is stored in 5-gallon tin cans which contain 60 pounds of honey. It is desirable that the cans of honey be stored in a dry place at a temperature as near 70° F. as possible. Higher temperatures over long periods will result in discoloration and a lowering of the quality of the honey, while lower temperatures are inducive to granulation. If stored where there is moisture, the cans rust, becoming unattractive and even unacceptable on the market. Oiling the cans with a thin coat of fine oil will prevent, or at least retard, their rusting in storage.

Usually, the beekeeper will find it advisable to dispose of his crop as quickly as possible, thus eliminating the problems of storage, reliquefying, packaging, and marketing. The temperatures of most honey houses in winter are ideal for granulation of honeys (50° to 65° F.). The possibility of loss through fermentation, particularly of honeys which have not been well ripened, when carried over until warm weather or when placed in warm storage, presents another problem. For additional information concerning storage temperatures, see Chapter XV, entitled "Honey."

## Summary of Recommended Measures

Because honey is extracted and processed in contact with the air and the surfaces of the equipment, as much care should be taken to produce a clean, wholesome product as with any other food. The extracting plant and its equipment should be kept freshly painted and spotlessly clean. This is especially true of the cracks and crevices of tanks and pipe fittings which cause discoloration and deterioration of the quality of honey which remains in contact with the metal in the presence of heat. Such places also often hold crystals of granulated honey which induce granulation.

The honey to be extracted should be well ripened, and honeys from different plant sources should be extracted separately whenever possible. All honey removed from diseased colonies or from apiaries where disease is prevalent should be kept separate and extracted after all other honeys, after which the equipment should be thoroughly cleaned and sterilized.

Honey should be heated only to facilitate its handling and to prevent or retard granulation and fermentation. A minimum amount of honey should be exposed to the heat source and should flow away quickly. The honey from most cappings melters should not be added to the rest of the crop because it may have been injured in quality. The honey should be strained thoroughly to clean it, and allowed to settle until it is clear. It should be drawn into containers, sealed while hot, and the containers set apart for cooling. It always should be kept in mind that a fine, wholesome, natural food is being prepared for human consumption.

FIGURE 172a. Merchandising honey in the modern manner. Mrs. Carl E. Killion with a display of extracted and fancy comb honey in a food market demonstrates the exceptionally fine food value of honey and how to use it on the table and in cooking and baking. (*Photo courtesy Carl E. Killion*)

# XII. *The Production of Comb Honey*

BY CARL E. KILLION*

COMB HONEY does not require a great many words to describe it. In fact, it tells its own story without words—pure honey in its natural, original state. The perfume of the blossoms is enclosed in each individual cell. The structure and finish of honeycomb is a thing of beauty. Comb honey cannot be duplicated by man; it is only the honey bee that can perform this work of art.

The amount of comb honey produced has decreased steadily since the beginning of the century. This decline was greatest in the two World War periods which created a serious sugar shortage and a great demand for liquid honey at a high price. However, when sugar again became plentiful following World War II, extracted honey no longer found a ready market. This has resulted in a tendency for many to return to the production of comb honey and bulk comb honey.

Comb honey should be produced in an area where white- or light-colored honeys of good flavor are produced. Areas which produce dark-colored honeys, or a mixture of light- and dark-colored honeys, are not suitable for its production because the comb honey is not attractive and does not find a ready market. It is difficult to produce comb honey where the nectar flow is light. The heavier the flow, the easier it is for the beekeeper to produce a crop. In a heavy flow the bees will build the comb more fragile which improves the eating qualities.

Areas where bees gather an excessive amount of propolis, such as wooded sections, are to be avoided by the comb honey producer as much more work will be required to clean the sections when preparing them for market. However, partial shade often is desirable to help keep the colonies and supers of honey cooler in the heat of summer. Areas which produce honeys that granulate quickly also are not preferred for the production of comb honey.

Seasonal management of colonies producing comb honey is very much like that for the production of extracted honey, *except during the honey-flow.* Any plan of management which will build all colonies to maxi-

***Carl E. Killion. Chief apiary inspector of Illinois. Proprietor of Killion & Sons Apiaries, Paris, Illinois, devoted to the production of fancy comb honey.**

mum strength by the beginning of the principal honeyflow is a good plan to follow (see Chapter X, "Management for Extracted Honey Production").

The production of comb honey calls for more intensive supervision and manipulation of individual colonies than does the production of extracted honey. However, any person who is careful and exacting in handling bees should be able to produce comb honey. The beekeeper's work must be carefully planned and colonies must be operated with the most exacting precision. The problem of swarm control is greater and many of the preventive measures practiced by the extracted honey producer cannot be used. Colonies must be crowded to get fancy heavyweight sections. This crowded condition is an invitation to swarm. After the crop has been produced, it must be marketed and consumed before the honey starts to granulate in the combs. Comb honey requires careful handling at all times. If sold to distant markets, it must be packed in carriers which are cushioned on the bottom and sides.

Quality comb honey will always find a ready market. It is a natural product, clean and attractive in appearance, and a conveniently sized package for the consumer. The delicate aroma and flavor of the honey in the comb has not been injured by heating and processing, as is sometimes the case with extracted honey. The equipment needed to prepare comb honey for market is less expensive than that required for processing extracted honey.

## Comb Honey Equipment

Inasmuch as the ten-frame Langstroth hive is used most widely in comb honey production, it might be assumed that this is the best size of hive. The eight-frame hive, used by many of the masterful comb honey producers in the past, still is used in a limited way. Usually, two eight-frame or ten-frame hive bodies are used to contain the queen and her brood prior to contracting the brood nest at the time of supering. During the past few years, the use of pollen supplement has enabled colonies to develop to the size of three hive bodies at the start of the main honeyflow. The use of nine frames and a follower board on each side has proved to be a good arrangement for brood chambers (Fig. 173). The follower board serves to insulate and to ventilate the brood chamber.

### Sections

Sections are made from carefully selected basswood, sanded smooth, one-eighth inch in thickness, grooved for folding, and dovetailed on the two ends for fitting together and holding when folded. It is important that the sections be milled properly and that they be accurate in size. Sections that do not fold squarely should not be used, and those that are not full size will result in sections of comb honey being light in weight.

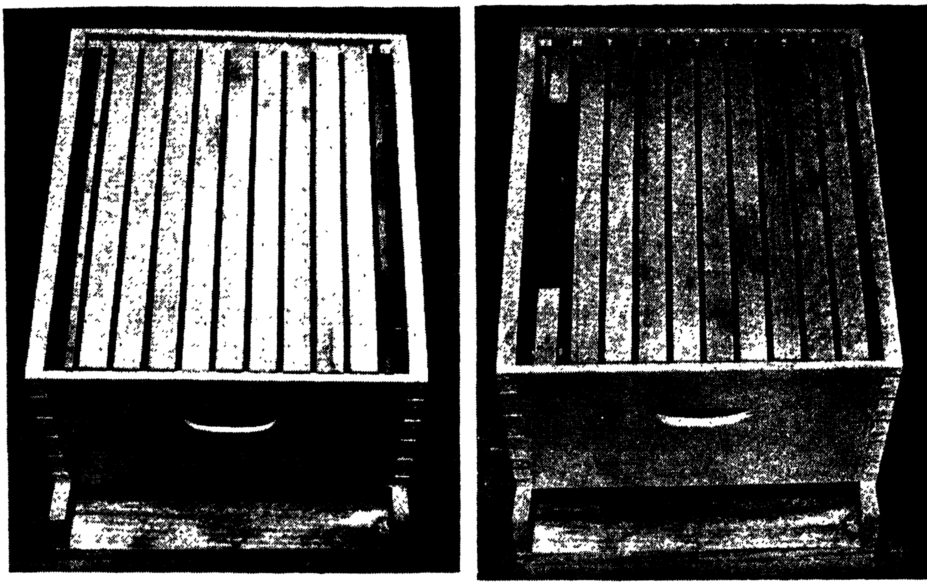


FIGURE 173. At left is the hive containing nine frames and a follower board on each side, and resting on a deep bottom board. The follower boards and the deep bottom board provide for improved ventilation. At right is the same hive with the two follower boards removed and the feeder in place at the left side of the hive. (*Photos by Killion Photo Service*)

Sections may be folded by hand or by means of a section press, by which the section is pressed together firmly and squarely. In some devices, the section press is combined with a foundation fastener. When sections are too dry to fold without breaking, the boxes containing them should be placed on a damp concrete floor several days before the sections are to be folded. The floor may be sprinkled and the containers turned to allow the moisture to penetrate all of the V-grooves. A dampened rug or carpet thrown over the boxes is a great help, or the cartons containing the sections can be opened along the side and water carefully poured down the V-grooves to moisten them. The sections should not remain damp for many days or the wood will mildew, staining the sections.

The *beeway section* is scalloped along the sides of the top and bottom of the section allowing vertical passage of the bees (Fig. 174). The beeway section having dimensions of 4¼ by 4¼ by 1⅞ inches is most popular and is used widely. *Plain sections* do not have the sides scalloped as above, the most common sizes being 4¼ by 4¼ by 1½ inches and 4 by 5 by 1⅜ inches.

Sections are placed in rows of four in the supers and, in order to effect an easier and quicker method of inserting the foundation, manufacturers in recent years have split the section by a saw kerf in the center of three sides. When the sections are folded and placed in rows of four, a full sheet of foundation can be inserted in the four sections in one operation. Such sections are called *split sections.*

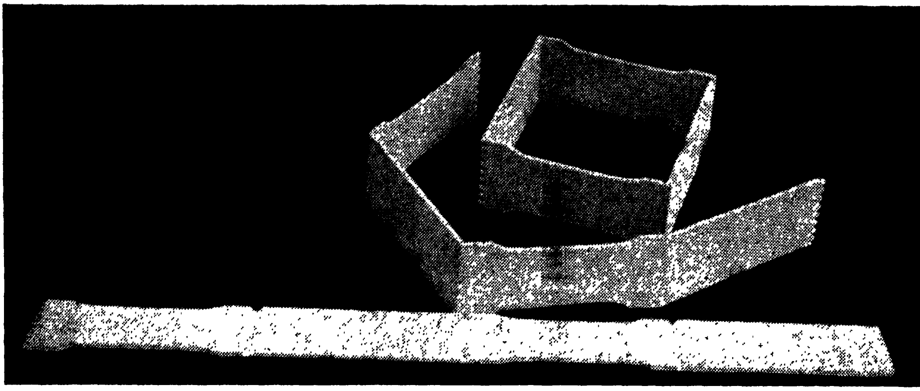


FIGURE 174. The beeway section, scalloped along the top and bottom for vertical passage of bees, is used by many.

### FOUNDATION FOR SECTIONS

Only the clearest, lightest colored, and thinnest grade of foundation should be used in sections. This grade of foundation is known as *thin super* or *thin surplus*. Medium brood foundation never should be used in sections. For additional information on foundation for section comb honey, see Chapter VI, "Beekeeping Equipment."

When the 4¼-inch square split sections are used, a full sheet of foundation size 4⅛ by 17 inches can be inserted through the groove of the four sections. For the 4 by 5-inch split section, the size of the full sheet of foundation should be 4⅞ by 16 inches. The split section is popular and the sheet of foundation, when inserted in the four sections, has the rows of cells running horizontally with the hexagons pointing vertically.

For sections which are not split, it is necessary to cut the sheets of foundation into sizes to fit the individual sections. Sheets of foundation measuring 3⅞ by 16½ inches are used for both beeway and plain 4¼-inch sections. For the 4 by 5 by 1⅜-inch section, the size of foundation is 3 11/16 by 14¼ inches. For best results a top and bottom starter should be used. The bottom starter is ⅝ inch in width and the top starter extends to within ¼ inch of the bottom starter. The small space between the foundation allows for the slight stretching usual in very light comb foundation, and the two starters provide nearly a full sheet of foundation in the section, thus insuring better fastening at the top and bottom of the section and a better filled section. The ideal length of foundation for cutting both the top and bottom starters for the 4¼-inch square section is 15⅜ inches.

### CUTTING FOUNDATION FOR SECTIONS

To cut the foundation quickly and accurately a cutting box should be used. The cutting box can be purchased, or made in any beekeeper's workshop. It should be made accurately to accommodate the particular

size of foundation used. There are four saw kerfs, but the one near the open end is not used except when the foundation is longer than 15⅜ inches. The box is about 2 inches deep, 4 1/16 inches wide, and the sides are 16½ inches in length. The box can be nailed to a piece of plywood, somewhat larger than its base, in order to fasten it to the worktable to hold it in position while cutting.

A thin knife, such as a scalloped slicing knife, is used with a sawing motion to cut the beeswax foundation. A better one can be made by getting a blade from a bread slicing machine and mounting the blade in a hack saw or similar frame (Fig. 175). A temperature near 70° F. is about correct for cutting; if the temperature is too cool, the foundation will shatter along the cut edges. The cutting box can be filled to within ¼ inch of the top. The foundation, held lightly by the left hand, is cut into squares. Then the foundation squares are removed and a small block which is the width of the bottom starter (⅝ by 2 by 3⅞ inches) is inserted into the box against the closed end. The block causes the foundation to extend beyond the saw kerf the exact width of the bottom starter (Fig. 175). As each stack of foundation is picked up to be placed in the cutting box again for cutting the bottom starters, it should be turned at

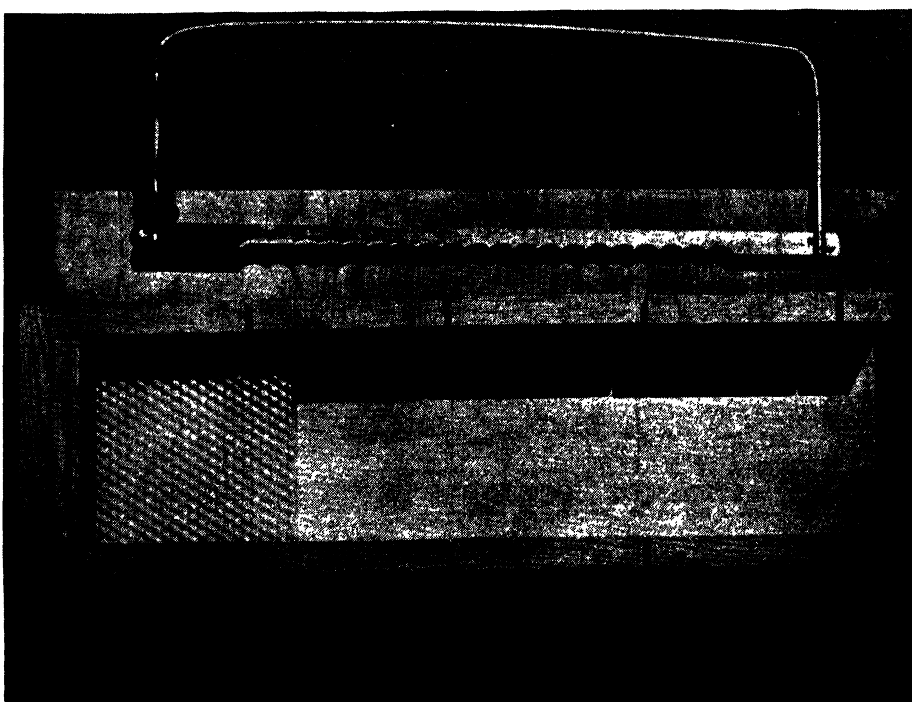


FIGURE 175. The cutting box and scalloped slicing knife. The foundation has been cut into squares, and the block has been inserted into the box at the closed end for cutting the bottom starters. (*Photo by Killion Photo Service*)

right angles to its original position. This allows the foundation, when placed in the section, to have the rows of cells running horizontally.

### Fastening the Foundation

A most satisfactory and efficient method for fastening the foundation in the sections is the use of the multiple-block board and hot plate (Fig. 176). The twelve blocks three deep and four wide, are 3⅝ inches square, ⅞ inch in thickness, and spaced 11/16 inch apart. Before using the board of blocks, it should be painted with linseed or paraffin oil. When used in warm weather, a small amount of vaseline smoothed on each block allows the foundation to slide across easily.

Aluminum is the best material for the hot plate. The blade of the hot plate, 3⅞ inches broad and 2½ inches deep, is heated by a small kerosene stove. The blade should be heated enough to melt the wax sufficiently for the foundation to adhere to the wood section properly. If the blade is too hot, the wax and the section may be discolored. If the room temperature is from 55° to 65° F., better and swifter fastening will result because the foundation starters are stiff and handle more readily.

As the folded sections are placed on the blocks, the tops of the four sections in each row should be farthest away, with the bottoms having the dovetails nearest the operator. The entire board is then given a one-

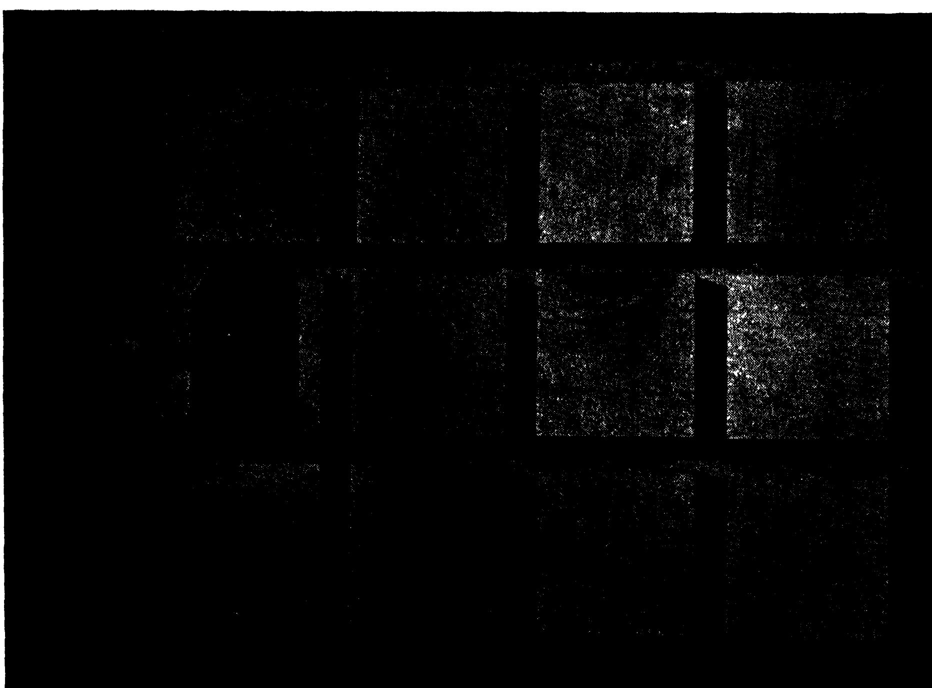


FIGURE 176. The multiple-block board, with the hot plate at left, ready for fastening the foundation in the sections. (*Photo by Killion Photo Service*)

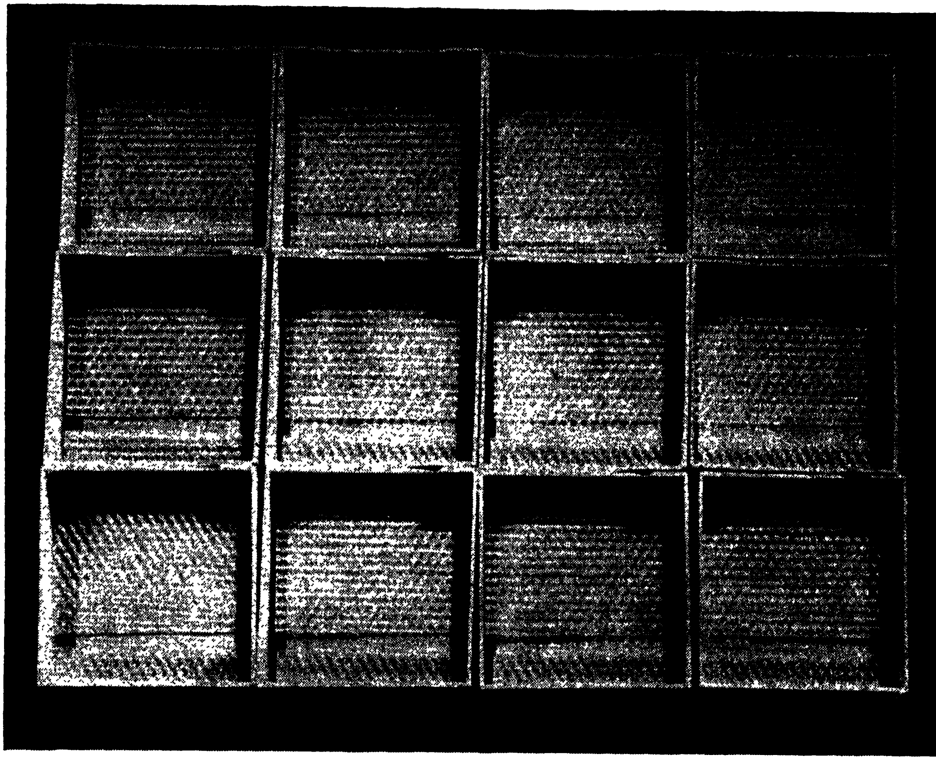


FIGURE 177. The three rows of sections with the foundation fastened in place, resting on the multiple-block board. (*Photo by Killion Photo Service*)

quarter turn counter-clockwise and the board tilted to slide the sections to the right, making openings between the blocks and the bottoms of the sections. Twelve of the small bottom starters are then placed in proper position on the blocks. The heated plate, held in the right hand, is lowered into the opening between the block and the section, and at the same time the left hand guides the foundation against the plate. The plate is withdrawn quickly and the foundation is forced against the wood of the section with a slight pressure to fasten the bottom starter.

The board is now turned clockwise until the bottoms of the sections are to the left and the board tilted to cause the sections to slide to the right, making openings between the blocks and the tops of the sections. The larger top starters are then fastened in a similar manner (Fig. 177). Each row of four sections then is lifted off the block, turned upward in the correct position, and placed in the super. The blocks are now ready to receive twelve more sections. Drops of wax which collect on the blocks and the board must be removed from time to time or they will interfere with the sliding of the sections and the starters.

Some beekeepers use a single block mounted on a board while others use various types of apparatus available on the market for fastening

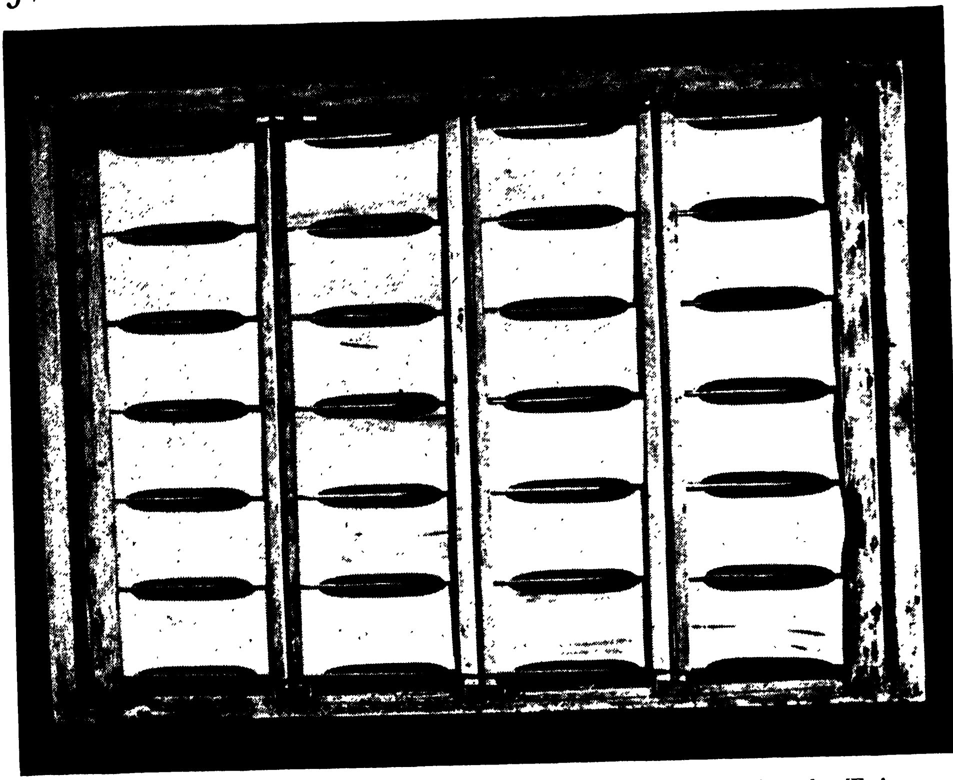


FIGURE 178. Bottom view of the Air-way, or ventilated T-super, showing the T-tins and how they support the rows of sections. (*Photo by Killion Photo Service*)

foundation. All operate on the same principle as the multiple-block board, the method used depending on the requirements and the preference of the individual beekeeper.

## COMB HONEY SUPERS

Comb honey supers differ in the method of supporting the sections, protection to the outsides of the sections, and the degree of free communication from section to section. The two types in general use are the super equipped with beeway section holders, or with plain section holders, and the T-super in which the sections are supported by strips of tin shaped like an inverted "T" (Fig. 178). The super equipped with beeway section holders is used more generally than any other and affords protection for the bottoms of the sections, while the T-super protects neither top nor bottom.

When the beeway sections are used in either type of super, passageway is afforded for the bees from top to bottom. Scalloped or beeway separators are used between the rows of sections, preventing the bees from bulging one section out too far and into the space occupied by an adjoining section. When either of the plain sections is used with the plain sec-

tion holder, fences are used which are cleated on each side with narrow strips. The narrow strips hold the sections apart and permit vertical passage of the bees, while openings in the fence permit horizontal passage between the sections. A similar fence is used with plain sections in the T-super, the fence resting on the tops of the T-tins.

The Air-way super,[1] although used in a limited area, merits mention as an improvement over the T-super used by Dr. C. C. Miller (Fig. 179). In the T-super the sections are crowded together against one side of the hive and the sections in the row next to the wall of the hive usually are not fully drawn and, therefore, of a poorer grade. The Air-way super is ventilated on all four sides by air spaces and is an improvement by Charles A. Kruse. Besides the advantage of improved ventilation, the rows of sections on either side of the super are fully drawn, with the corner sections being as perfect as the ones in the center. Also there is less travel stain on the combs than in any other type of super.

One should provide well in advance enough supers to take care of the largest possible crop, although the exact number necessary for each colony cannot be determined. Supers that are not used can be set aside for the next season and should be well protected from heat, dust, and moisture. Cold is not harmful unless the supers are moved during cold weather.

### Bait Sections

In the preparation of supers, an estimate should be made of the number of colonies to be used for producing comb honey and one bait-section super should be prepared for each colony. One section containing empty comb, free of honey, is placed near the center of the super, the rest of the sections containing foundation. The bait-section supers should be stored where they can be reached easily as they are the first supers to be used. In preparing the comb honey for the market, the bait sections should never be used because the comb is always much tougher than that of sections recently drawn from foundation. They should be melted up or consumed at home.

### Paraffin to Prevent Propolis

After the sections, separators, and springs are placed in the supers, the tops of the sections should be painted with paraffin to keep the wood clean. Those using T-supers should paint both the tops and the bottoms of the sections. The paraffin may be melted in any suitable container and should be heated to a temperature of 330° to 350° F. A lower temperature will result in the coating being too thick; a higher temperature will darken the wood. The sections are painted one row at a time with a 2-inch brush, and any joints not covered should be stroked crosswise. Propolis on sections is a nuisance as it is difficult to remove and contributes to travel staining of the comb surfaces.

[1] Killion, Carl E. 1940. Comb honey. *Amer. Bee Jour.* 80:310-312.

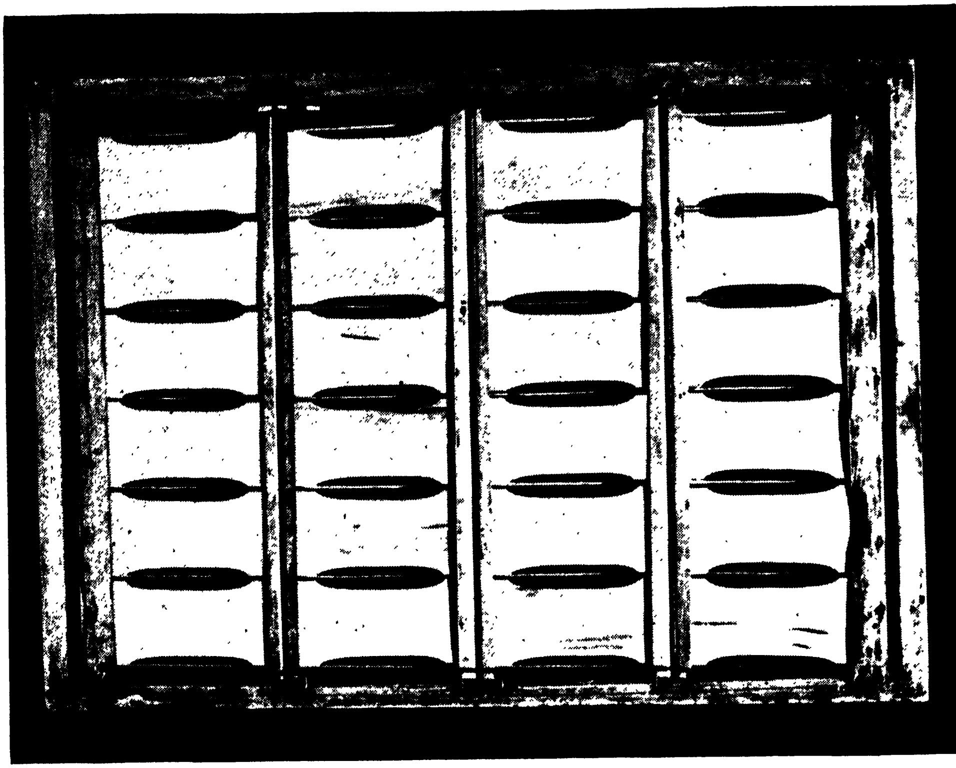


FIGURE 178. Bottom view of the Air-way, or ventilated T-super, showing the T-tins and how they support the rows of sections. (*Photo by Killion Photo Service*)

foundation. All operate on the same principle as the multiple-block board, the method used depending on the requirements and the preference of the individual beekeeper.

## COMB HONEY SUPERS

Comb honey supers differ in the method of supporting the sections, protection to the outsides of the sections, and the degree of free communication from section to section. The two types in general use are the super equipped with beeway section holders, or with plain section holders, and the T-super in which the sections are supported by strips of tin shaped like an inverted "T" (Fig. 178). The super equipped with beeway section holders is used more generally than any other and affords protection for the bottoms of the sections, while the T-super protects neither top nor bottom.

When the beeway sections are used in either type of super, passageway is afforded for the bees from top to bottom. Scalloped or beeway separators are used between the rows of sections, preventing the bees from bulging one section out too far and into the space occupied by an adjoining section. When either of the plain sections is used with the plain sec-

tion holder, fences are used which are cleated on each side with narrow strips. The narrow strips hold the sections apart and permit vertical passage of the bees, while openings in the fence permit horizontal passage between the sections. A similar fence is used with plain sections in the T-super, the fence resting on the tops of the T-tins.

The Air-way super,[1] although used in a limited area, merits mention as an improvement over the T-super used by Dr. C. C. Miller (Fig. 179). In the T-super the sections are crowded together against one side of the hive and the sections in the row next to the wall of the hive usually are not fully drawn and, therefore, of a poorer grade. The Air-way super is ventilated on all four sides by air spaces and is an improvement by Charles A. Kruse. Besides the advantage of improved ventilation, the rows of sections on either side of the super are fully drawn, with the corner sections being as perfect as the ones in the center. Also there is less travel stain on the combs than in any other type of super.

One should provide well in advance enough supers to take care of the largest possible crop, although the exact number necessary for each colony cannot be determined. Supers that are not used can be set aside for the next season and should be well protected from heat, dust, and moisture. Cold is not harmful unless the supers are moved during cold weather.

### Bait Sections

In the preparation of supers, an estimate should be made of the number of colonies to be used for producing comb honey and one bait-section super should be prepared for each colony. One section containing empty comb, free of honey, is placed near the center of the super, the rest of the sections containing foundation. The bait-section supers should be stored where they can be reached easily as they are the first supers to be used. In preparing the comb honey for the market, the bait sections should never be used because the comb is always much tougher than that of sections recently drawn from foundation. They should be melted up or consumed at home.

### Paraffin to Prevent Propolis

After the sections, separators, and springs are placed in the supers, the tops of the sections should be painted with paraffin to keep the wood clean. Those using T-supers should paint both the tops and the bottoms of the sections. The paraffin may be melted in any suitable container and should be heated to a temperature of 330° to 350° F. A lower temperature will result in the coating being too thick; a higher temperature will darken the wood. The sections are painted one row at a time with a 2-inch brush, and any joints not covered should be stroked crosswise. Propolis on sections is a nuisance as it is difficult to remove and contributes to travel staining of the comb surfaces.

[1] Killion, Carl E. 1940. Comb honey. *Amer. Bee Jour.* 80:310-312.

## Apiary Management For Comb Honey

In producing honey, whether comb or extracted, the beekeeper should remember that his colonies should be strongest in field bees at the start of the expected honeyflow. This is important because each honeyflow usually lasts but a few weeks. George S. Demuth often said, "We must rear bees *for the harvest* and not *on the harvest.*"

Only strong colonies should be used for producing comb honey, and only those colonies that work best in foundation supers should be used. Weak colonies either should be used to strengthen other colonies or to produce extracted honey. In fact, most comb honey producers use some colonies for the production of extracted honey.

Regardless of whether colonies are in two or three hive bodies at the start of the honeyflow, *each is always reduced to a single hive body when the first comb honey super is given.* In most cases, the upper hive body

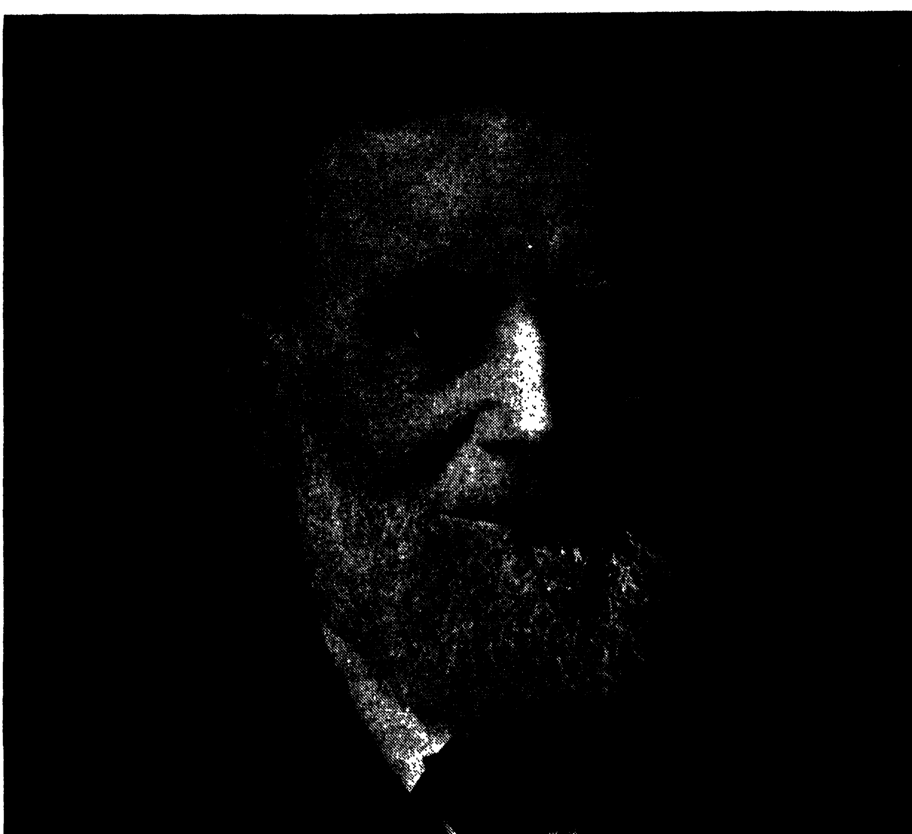


FIGURE 179. Dr. Charles C. Miller, one of the most beloved authorities on beekeeping, was one of our most successful comb honey producers.

which is heavy with fresh nectar all around the brood is left with the parent stand. Fresh nectar coming in, therefore, must go into the comb honey super. Should the weather suddenly turn cool and rainy for several days, the colony will not starve. The queen must be left in the hive body on the parent stand to which the first comb honey super has been given. Most of the bees from the bodies that are removed should be shaken in front of the entrance of the parent colony. The removed bodies of brood can be used for increase or to strengthen weak colonies. If filled with honey during the flow, they may be returned to the parent colony for winter stores, after the comb honey supers have been removed.

Queen excluders are seldom used in producing comb honey; instances where the queen enters the supers for brood rearing are rare. Sometimes a super of empty drawn sections, placed directly over the brood chamber, is an invitation for the queen to lay in them. Sections in which the foundation has fallen usually are rebuilt with drone comb and sometimes contain drone brood. A colony with many drones cannot produce as much surplus honey as one with few drones, thus every prevention of their occurrence represents an annual savings. However, when comb honey supers are handled carefully to keep the foundation in place and only one bait section is used in the first super given the colony, the queen excluder is not needed. Queen excluders also interfere with hive ventilation so urgently needed in comb honey production.

## Swarm-Control Measures

When colonies are exceptionally strong, they are likely to swarm when reduced to a single hive body. The reduction of a big powerful colony to one hive body containing all the bees—the brood chamber filled with brood and honey with scarcely any space for the queen to lay—their storage room only one super of tiny compartments—all is an invitation to swarm. Swarm-control measures must then be taken. The fact that comb honey production calls for extreme control over swarming discourages many from producing it.

Some of the preventive measures practiced by the extracted honey producer, such as giving abundant room, unlimited ventilation, empty drawn combs, and clearing the brood nest, cannot be used. For several years the author has tried numerous swarm-control methods, but the one that has given the best results with a minimum of labor and extra equipment is given below.

A few days after the colonies are reduced to a single hive body, queen cells begin to be found in some colonies. Some years the bees may be just a little slow in their swarming preparations, and only a few cells will be present in such colonies on the first visit, and these are destroyed. Three or 4 days later when queen cells are again present in these colonies, and other colonies are also found with cells, the old queens are killed and all cells are destroyed. About 4 days after killing the queens, each colony is

examined again and all freshly constructed queen cells are destroyed. On the eighth day after killing the queens, every queen cell is again destroyed, and each colony either is given a young laying queen or a ripe queen cell. If a young laying queen is given, she should have just started to lay, not one that is several weeks old, or the colony may swarm about the middle of the honeyflow. If a ripe queen cell is used, it should be a grafted queen cell from the very best comb honey stock, and not a swarm cell.

After requeening the colony, it may then be crowded, as described below, to produce full-weight fancy sections. The beekeeper can do several things to increase the comfort of his colonies which may add to the quality of the honey produced. He can supply shade in the form of shade boards, if natural shade is not available. Deep bottom boards of the Dr. Miller type can be used which will give more ventilation. If deep bottom boards are not available, the hive body can be raised on small wooden blocks at each corner. For additional information on swarming, see Chapter IX, "Common Practices in Management."

### Supering

When the first super is given, the bees should start drawing the foundation at once. Depending on the intensity of the flow and the strength of the colony, the first super should be one-half, two-thirds, or three-fourths full before the second super is added. When a new super is given, it should always be placed on top of the other supers already on the hive. On the next trip the second super is placed next to the brood and the first super is placed on top. If the colony is ready for a third super it is added on top. Before giving the third super, the first super should be nearly full and the second super at least one-half full. In an exceptionally heavy flow, the third super can be given before the second super is one-half full, but it is better to crowd the colony just a little than to give it super room too far in advance. One serious mistake made by many beekeepers is to give comb honey supers too fast or too many at one time.

If the next trip reveals that the third super is being drawn rapidly, it is placed next to the brood with the second super above it, and the first

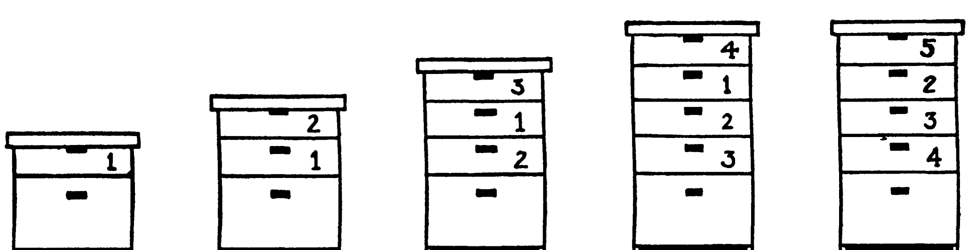



Figure 180. Diagram showing the method of supering. The supers are numbered in the order in which they are given.

super on top. If the fourth super is needed it is added on top. As soon as a super is completely capped over or finished, it should be removed to eliminate all unnecessary travel stain on the cappings, and the handling of the super with each manipulation. The next visit may necessitate the giving of the fifth super and the removal of the first super. The proper order of supering is shown in Fig. 180. It should be advised that comb honey supers cannot be staggered, leaving openings for additional ventilation, as practiced with extracted honey supers. Such practice will cause the bees to leave sections unfinished near these cracks or openings.

### Removal of Supers

Before the escape board is placed under the super to be removed, the super is placed on top of the hive, given a few puffs of smoke to start the bees running down, and then lifted off quickly and given a few vigorous shakes in front of the hive. The smoking and shaking dislodge many bees, and the super, when placed over the escape board, is emptied of bees more quickly. In smoking, care should be used that soot from the smoker does not blow on the sections of comb, thus ruining the comb honey. The escape board is placed under the super and care is used to see that the super is bee tight to prevent robbing, and shaded to prevent the comb melting down from the heat of the sun.

It will be noticed that the sections farthest from the entrance usually are further advanced than those in front. This can be remedied by reversing the super each time it is handled. Dr. Miller removed the entire super when nearly filled without waiting for the outside sections to be filled. Unfinished sections of several supers were then put together and given back to a strong colony to be finished.

As the season advances, one cannot continue to give supers as freely as in the earlier part of the flow. The weather, the honey plants, the ground moisture, and the condition of the colonies must be considered at all times toward the end of the flow.

## Care of Comb Honey

It should always be remembered that one cannot handle comb honey too carefully. A section once damaged can never be repaired. Supers brought into the honey house should be stacked tightly, preferably not over 15 supers high. The stacks should be arranged so that each can be fumigated immediately after they are brought from the apiary, and again every 5 or 6 days, to prevent damage by the larvae of the wax moth until the sections are sealed in the shipping cases. Sulfur or carbon disulfide generally are used as fumigants. Paradichlorobenzene (PDB) should never be used as the odor of the crystals is absorbed by the honey, ruining its flavor. For methods of fumigating and precautions in regard to the use of fumigants, see Chapter XXIII, "Diseases and Enemies of the Honey

Bee." To avoid granulation of honey in the comb, comb honey should be stored at temperatures ranging from 70° to 90° F. The temperature should never go below 70°, and comb honey seems to keep best at about 80° to 85° F.

Comb honey should receive the most thorough preparation for the market and the very strictest grading. A product as attractive as a fancy section of comb honey should be sent to market in perfect condition and in a fancy dress. The beekeeper's hands should be clean whenever sections are handled, for there is nothing quite so untidy as a section marked with fingerprints. For information regarding the preparation of comb honey for the market, see Chapter XVI, "Marketing the Honey Crop." For treatment of unmarketable sections or culls, see Chapter XIII, "The Production of Bulk Comb Honey."

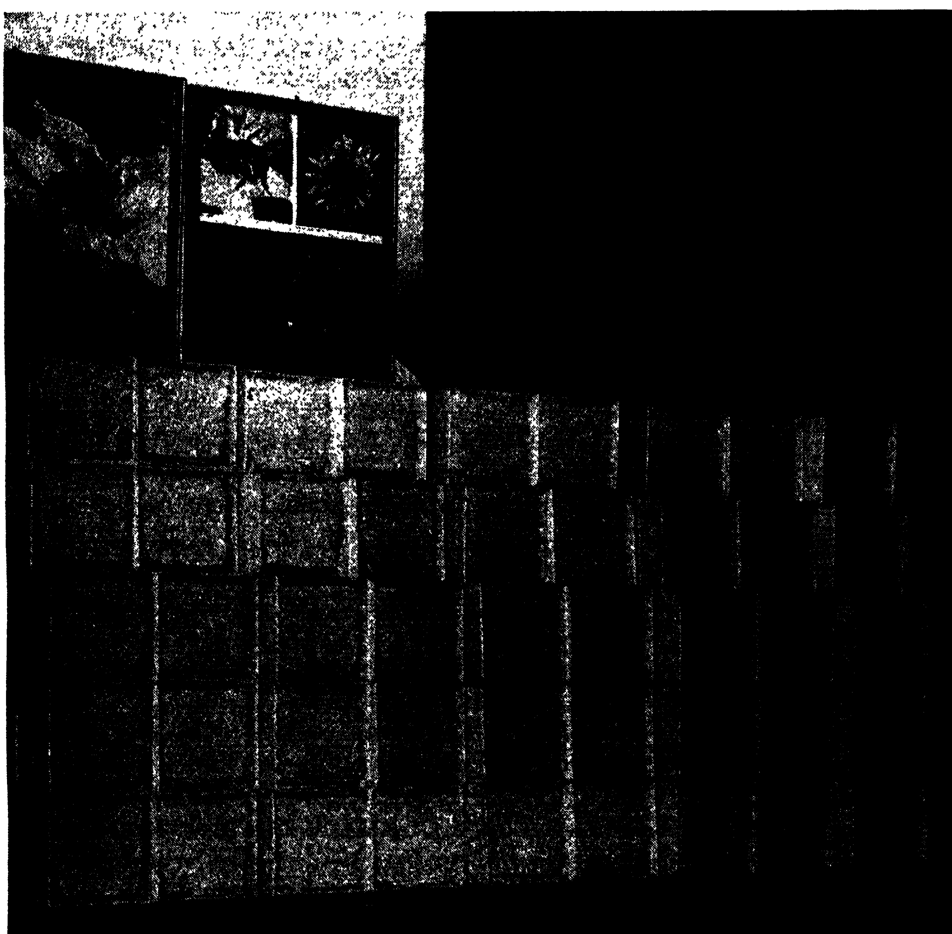


FIGURE 180a. A large display of fancy section comb honey. Even when not wrapped in cellophane, it makes a lovely product. (*Photo courtesy Carl E. Killion*)

# XIII. *The Production of Bulk Comb Honey*

BY NEWMAN I. LYLE*

BULK comb honey, used in preparing chunk honey or cut comb honey, is usually produced in shallow supers much as honey is produced for extracting. Instead of using the heavier medium brood foundation reinforced with wires, sheets of thin super or surplus grades of foundation are used in the shallow frames. The resulting combs of honey are too fragile to extract, being as delicate as section comb honey. The only difference, therefore, between bulk comb and section comb honey is in the size of the combs, the slabs of honey weighing from 3½ to 4 pounds each.

The combs can be cut into any desired size for table use or for sale. When cut into individual pieces, drained, and wrapped in cellophane, the resulting product is called *cut comb honey.* When the individual pieces are packed in pails or glass jars and liquid honey is poured around them to fill the container, the product is called *chunk honey.* Chunk honey usually consists of 40 per cent or more of bulk comb honey and 60 per cent or less of liquid extracted honey (see Chapter XV, entitled "Honey").

Less equipment is required for the production and processing of bulk comb honey than is needed for the producing and handling of extracted honey. The bulk comb honey supers may be turned to extracted honey production at any time by inserting medium brood foundation in the super frames. Inasmuch as the production of bulk comb honey requires a somewhat different management than either the production of comb honey or extracted honey, even the experienced beekeeper is advised to change to the production of bulk comb honey gradually, while learning how to manage his bees for this purpose. In localities where the honey-flow is light or short, bulk comb honey production is usually unprofitable.

Before entering the production of bulk comb honey, a survey should be made to determine whether it would be better to produce this form of honey for sale under contract to a packer or to attempt local distribution. In either case, the demand for the product and the amount of honey necessary to supply that demand should be ascertained.

---

*Newman I. Lyle. Commercial honey producer. Formerly extension apiarist, Iowa State College. Formerly special field agent in beekeeping, U.S.D.A. Twenty years' experience in the production of bulk comb honey.

While bees like to work in shallow frames better than in comb-honey sections and will produce more bulk comb honey than they will section comb honey, they will not ~~produce~~ as much bulk comb honey as they will extracted honey. The amount of bulk comb honey produced usually averages about half way between the possible production of comb honey and of extracted honey. The price obtained for bulk comb honey then should net the producer about 30 to 50 per cent more than he can secure for extracted honey. When honey prices are low, the 50-per cent increase is about right; when prices are high, a 30-per cent increase over the price of extracted honey is more nearly correct.

In the production of section comb honey, the sections with thin surplus foundation are replaced each time the super is emptied. In bulk comb honey production, the shallow frames must be refilled each time with thin surplus foundation, requiring about 1 pound of foundation for every 70 pounds of honey produced.

## Preparation of Equipment

Some producers of bulk comb honey prepare their supers early in the spring. This is possible if a well-heated room is available in which to store them until they are needed. However, it is more advisable to prepare them as they are needed, for when the supers are used immediately there is less chance for waviness in the foundation. Later in the flow more may be prepared as they are needed. When this is done in a cool basement and the supers stored there until needed, they will reach the bees in excellent condition. The straighter the foundation the more even will be the resulting combs. When supers are prepared long in advance, some of the foundation may crack and break loose from the top bar of the frame.

It is poor economy to use less than full sheets of foundation in the shallow frames. Langstroth shallow frames require $4\frac{1}{2}$ by $16\frac{1}{2}$-inch size. Either thin surplus foundation or special bulk comb foundation may be used. The special bulk comb foundation will hold its shape better and the bees work it more readily because there is more wax in the cell walls. (Foundation is preferred which is milled with a straight edge and carefully packed so that the sheets stay flat.)

Three types of top bars are used in the production of bulk comb honey: the wedge top bar, the grooved top bar, and the slotted top bar. The wedge top bar is the same as that used for extracting or brood combs, the wedge being nailed in place to fasten the foundation. Since this takes considerable time, most prefer to wax the foundation in place in the top bars.

Form boards are a great convenience in inserting the sheets of foundation into the frames. They are the size of the inside of the frames and of a thickness that just reaches to the back edge of the cut-out portion of the

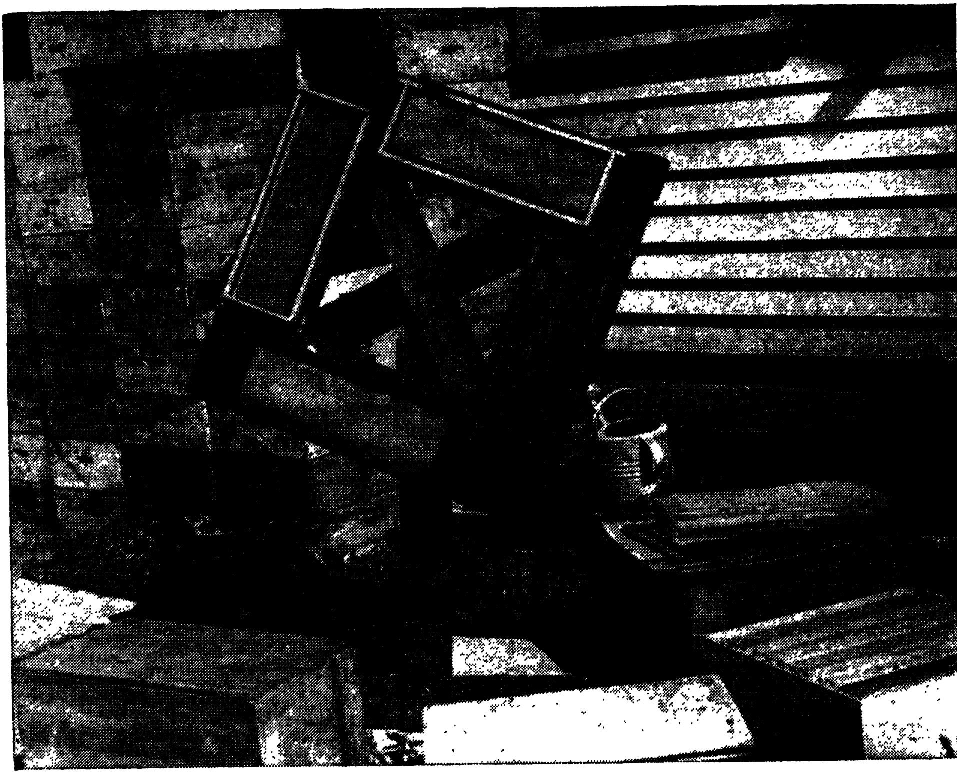


FIGURE 181. The reel holds four frames and is turned to facilitate waxing in the sheets of special bulk comb foundation. (*Photo courtesy Newman I. Lyle*)

wedge top bar, or the groove of the top bar, when the frame is laid over the board. Four or more of these form boards may be fastened to a reel for speed and convenience (Fig. 181). Frames are then placed over the form boards, each frame being held in position on the reel by a cleat parallel to the form board, and by a spring pressing against the outside of the frame end bar.

The foundation which is to be waxed into the frames should have been kept in a warm place for a time so that it is slightly pliable. A sheet of the warm foundation is placed on the lower form board of the reel and the edge of the foundation pushed into the groove of the top bar or into the corner of the wedge top bar.

Liquid beeswax is used to fasten the foundation in the frames. The beeswax may be melted in a gallon honey bucket on a grate in the bottom of a 12-quart bucket, the latter serving as a water jacket. Any type of portable stove may be used for heat. When the beeswax is melted and the water in the outer container is boiling gently, the temperature of the wax is correct. A teaspoon, having its tip pinched together to form a pouring spout and the handle bent up nearly at right angle to the bowl of the spoon, serves to convey the beeswax from the melting container.

The reel is turned so that one end of the frame is slightly higher than the other. A spoonful of the liquid wax is poured into the groove of the top bar, or into the corner of the wedge top bar, at the highest end and allowed to run down the length of the top bar. When the liquid wax reaches the lower end of the frame, the reel is turned quickly so that the frame is level. A few drops of wax then are placed at the corners of the foundation to reinforce the attachment to the top bar. When the wax has been applied, all the fingers are used quickly to push the sheet of foundation firmly into the groove and to hold it in position until it sets solidly in place. The wax must still be liquid when this is done or the operation will have to be repeated. If the foundation is not fastened solidly in place, the sheets are liable to come loose before the bees have a chance to build combs. There is no worse mess than combs constructed on foundation which has come loose and fallen out of position in the frames.

## Management Before the Honeyflow

As in the production of comb honey, only strong colonies with a well-balanced population should be used in the production of bulk comb honey. A prospective bulk comb honey colony should have four or five Langstroth frames well filled with brood about 6 weeks prior to the start of the main honeyflow. This is equivalent to three or four frames of brood in the Modified Dadant size. Colonies which do not have these minimum requirements should be operated for the production of extracted honey.

When colonies are in two ten-frame bodies, they should be reversed about 3 to 4 weeks before the main flow. With colonies in Modified Dadant hives the food chambers may be placed under the hive bodies at this time. The upper hive body, or food chamber, contains much of the brood area and nearly all of the honey left from the previous season. When the parts are reversed a division of the brood area is created causing prolific queens to do their utmost to unite the brood. The honey is carried up by the bees and placed around the brood where it is needed. This relocation of stores, in addition to the fresh nectar being gathered and the presence of an ample supply of pollen, greatly stimulates the colony. Old pollen in the combs is not as valuable as freshly gathered pollen. Progressive beekeepers now feed pollen supplements early in the spring to stimulate brood rearing (see Chapter XIV, "The Overwintering of Productive Colonies").

About 2 weeks later, depending on conditions, the colonies should be reversed again to their original arrangement. This will occur just before the main honeyflow when the colonies are becoming very powerful and are beginning to whiten their combs along the top bars in the brood nest. Combs of the food chambers thus are ready for the new supply of nectar for the next winter's stores.

At the same time, the first bulk comb honey super should be given on top of the colony. The bees will become accustomed to and will work them more readily when they need to do so. Later, even after the flow has started, if a brood chamber tends to become honeybound, the two hive bodies may be reversed again, thus helping to prevent the colony from loafing through the honeyflow. When the Modified Dadant hive and food chamber are used, the food chamber and the first bulk comb honey super may be reversed until the colony starts to work in the first super.

When all the colonies in a bee yard are to be used for producing bulk comb honey, weak colonies must be given special attention. In most cases the queens are substandard, even though they may have been reared the previous season. The queens may be killed and a 3-pound package of bees with a new queen united with each of the weak colonies. The colonies then will build up rapidly and have plenty of field bees at the time of the honeyflow. Usually, about one colony in ten requires this bolstering about 4 to 6 weeks before the beginning of the main honeyflow. A sufficient number of packages of bees should have been ordered to arrivé by that time.

At the time of the spring check, some colonies are found to be tremendously strong and these colonies will be ready for the honeyflow too early. They usually either will decline in their honey gathering ability or will swarm before the main flow. Brood and bees should be taken from each of them and given to colonies which need to be strengthened. The removed brood combs are replaced with empty combs or with combs of honey from the weaker colonies. Some beekeepers shake packages from the strong colonies and take them to other yards for strengthening weak ones. Care must be taken that the queen is not on any of the combs exchanged or shaken into the packages, and that combs or bees are not taken from, or given to, diseased colonies. This equalization program is planned so that all colonies will reach their peak strength just after the beginning of the main honeyflow. It also is a great aid in prevention of swarming.

## Manipulation of Supers

The first supers which are added should be baited. This can be done, when using the Modified Dadant hive with regular shallow supers, by exchanging two of the center frames of foundation with two of the outside combs of the food chamber. The bees will start work in the super on the two bait combs and will begin to draw the foundation. When they are well started with the drawing of the foundation, the bait combs may be exchanged with the original two of foundation in the food chamber, which should be partly drawn by this time. When shallow Langstroth supers are used (Fig. 182), bait combs may be obtained from those which were only partly drawn the previous season.

When colonies are so strong that they have brood in the two outer frames of the hive, the bait combs should be placed at the outer edges of the super. The bees then will work the super from the sides inward, often finishing all the combs at once. Many colonies, so baited, will continue to work their supers in this way as new ones are added, as long as the weather remains warm and the honeyflow is good.

A second bulk comb honey super is added when work is begun nicely in the first one. When work has started in this second super, the two supers are reversed and a third new super added on top. This method of "revolving" supers, adding the new one on top and putting the one previously added at the bottom, is continued well into the honeyflow. This keeps the bees spread throughout the entire stack of supers. They have work ahead of them at all times and there is little tendency for the brood nest to become honeybound. Toward the close of the flow, supers should be added sparingly to force the bees to finish the ones which they have so there will be a minimum of partially filled supers at the end of the season.

Some colonies have a tendency to confine their work to six or seven frames in the center of the super, even when bait combs are used. When this occurs, one half of the frames on one side of the super are taken out, turned around as a unit, and put back in their super; the other half of the frames are turned in a similar manner. Turning the supers "inside out" places the finished combs at the outside of the super and the bees then proceed to finish the entire super nicely.

Some colonies are poor comb finishers. These start work in the supers but do not cap the honey properly. Other colonies are good finishers, methodically completing the work in one super before beginning work

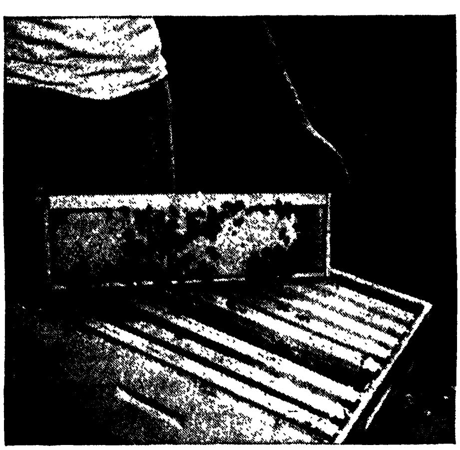


FIGURE 182. A shallow Langstroth super used for producing bulk comb honey. The comb has not been fully sealed over by the bees. (*Photo courtesy Caterpillar Tractor Co.*)

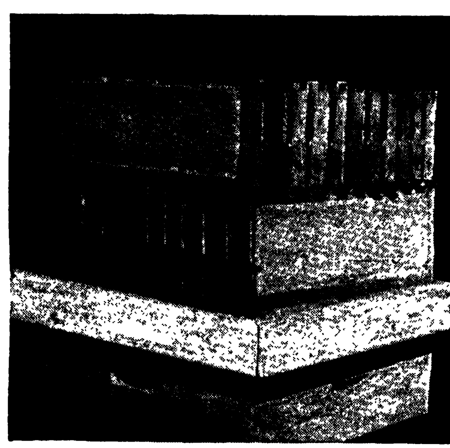


FIGURE 183. Bulb comb honey in shallow Modified Dadant frames. When capped clear to the bottom and ends of the frames, it is ready for market.

in another. When sufficiently filled with honey and before the combs are capped, supers from poor finishers should be given to good finishers for completion. Extracting supers of drawn comb are then given to the poor finishers and these colonies are not used further for producing bulk comb honey.

When bulk comb honey is being produced in conjunction with extracted honey, it is frequently possible to effect control over the swarming impulse by the use of bulk comb honey supers, even on colonies operated for extracted honey. There is a time at the peak of the honeyflow when nearly all colonies producing extracted honey seem to get the swarming fever at the same time. Apparently this is due to an ample supply of food and an abundance of worker bees of the right age to secrete beeswax. If these colonies are given a bulk comb honey super, the bees are able to use their surplus wax to build comb and seem to be content to remain at work. Under these conditions a super of bulk comb honey can be produced profitably by those colonies that are operated for the production of extracted honey. This overproduction of beeswax does not last for more than 10 days and then only when the honeyflow and weather conditions are just right.

Queen excluders seldom are used in the production of bulk comb honey. When two ten-frame bodies, or a Modified Dadant hive body with a food chamber, are used for the brood chamber there is a cushion of honey between the brood nest and the supers which keeps the queen from going into the supers in about 95 per cent of the cases. The use of queen excluders also tends to increase the desire to swarm rather than to prevent it.

The supers of bulk comb honey are removed as soon as the combs are capped clear to the bottom bars (Fig. 183). If supers are left on too long, bees will travel-stain the white cappings, causing the bulk comb honey to be unsuitable for marketing in comb form.

If the producer is under contract to a packer, the bulk comb honey is now ready for delivery, usually in the supers as it is removed from the hive. Reliable packers, who specialize in chunk honey or cut comb honey, wash and sterilize the supers before they are returned. Some packers even furnish supers for use in the production of bulk comb honey.

If the producer is to pack and sell his own crop, the supers are stored for cutting into chunk honey or cut comb honey as the trade demands. The supers should be stored in a fairly dry place and at temperatures, ranging from 70° to 90° F., that are favorable for preventing granulation of the honey in the combs. Since these temperatures also are favorable for the development of the wax moth, the supers should be stacked tightly and the stacks so arranged that each can be fumigated as often as necessary to prevent damage by the larvae of the wax moth. For information concerning fumigation for wax moth, see Chapter XXIII, "Diseases and Enemies of the Honey Bee."

## Cutting and Preparing for Market

There are various methods of preparing bulk comb honey for market. The following suggestions apply to the usual procedure. The combs are cut on a cutting board resting in a tray. The tray can be made from a 12-inch pine board, about 2½ feet long, having a rim on both sides and at one end made by nailing on strips about 2 inches wide. Two narrow cleats are nailed underneath the open end of the tray. The open end of the tray is placed over the edge of a tank, the cleats helping to hold the tray in position. A thin board, about 8 inches wide and 2 feet long, is lightly tacked to the center of the tray for a cutting board. The closed end is raised 2 or 3 inches higher than the open end of the tray so that the honey drippings will drain into the tank.

Within easy reach a small bucket of water is kept simmering over a gas plate or oil stove in order to heat two or three large-bladed paring knives used in cutting the comb honey. A frame of honey is taken from one of the supers and placed on the cutting board. With one of the heated, wet paring knives, a cut is made through the full length of the comb about an eighth of an inch from the wood of the top bar. The knife is exchanged for another heated knife and the same kind of cut is made along the bottom bar. The knives are again exchanged and similar cuts are made along each end bar. The frame now can be lifted off, the adhering honey and beeswax being scraped into the tank. Exchanging knives again, a piece of comb of the desired size is cut and placed where it is wanted. This process is repeated, changing knives with each cut as long as the work continues. When finished, or the tank is full, the scrapings and trimmings are cared for in the same manner as cappings from extracting combs (see Chapter XI, "Extracting the Honey Crop").

## Chunk Honey

When packing chunk honey, the pieces of comb are placed directly into the size of glass jar or tin pail required by the trade (Fig. 184). The containers are then filled with extracted honey which previously has been heated to 150° F. and allowed to cool to 120° by the time of filling. The extracted honey should be run down the sides of the containers to prevent incorporation of air bubbles. As fast as the containers are filled, the lids are placed on tightly and the containers laid on their sides so the comb will not be crushed by its own buoyancy in the warm honey. After cooling thoroughly, the containers may be packed in shipping cases.

Chunk honey should not be packaged and stored for a long time as granulation may ruin its sale. The surface of the comb honey tends to hasten crystal formation. Freshly packed chunk honey should be delivered to the store in small lots where it may be sold and consumed before

FIGURE 184. Chunk honey in glass containers having attractive labels is a package full of eye appeal for the customer—truly a picture package, comb honey and liquid honey in combination. (*Photo courtesy Sioux Honey Association*)

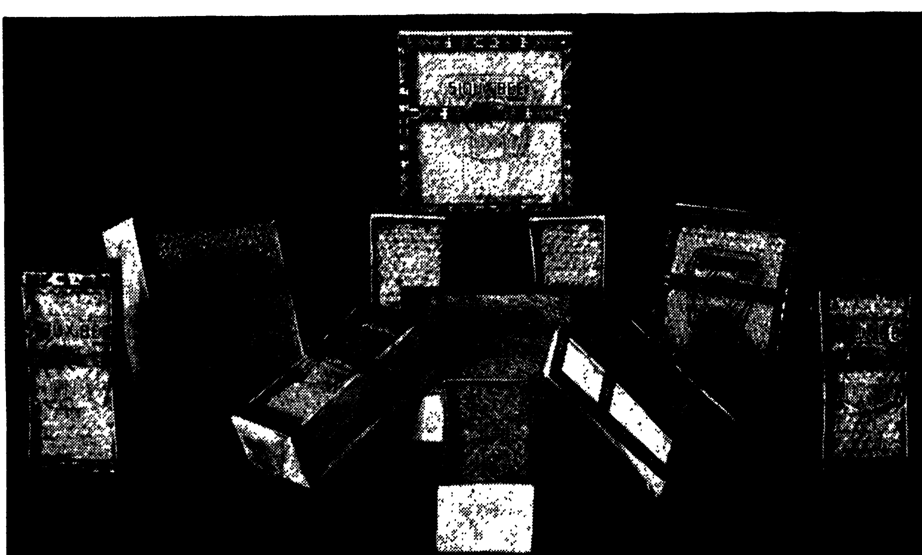


FIGURE 185. Cut comb honey wrapped in cellophane and placed in various styles of cartons—an enticing package which competes favorably with section comb honey on the retail market. (*Photo courtesy Sioux Honey Association*)

granulation occurs. If the storekeeper has an oversupply and the honey granulates, it should be replaced immediately with freshly packed honey.

The returned containers of honey may be placed in a warm oven at a temperature just under the melting point of beeswax (approximately 145° F.) until the granulated honey is entirely liquefied, when it can be placed again on the market. The containers also may be placed in hot water, and the comb melted and the contents emptied into a tank where the beeswax can be separated from the honey after cooling. This process may darken the honey causing it to be of inferior quality.

Consumers who like both comb honey and extracted honey usually will pay a higher price for this extra fancy product which has both kinds of honey in the same package. Also, some who are suspicious of honey purity will buy honey when it has a piece of comb visible in it. The glass package usually is preferred by the discriminating buyer.

To maintain a reputation as fancy honey, the chunk honey package must look its best. The honey must be of good flavor and the comb must be white, free from pollen, and cut neatly to a length that will extend from the top to the bottom of the container and to a breadth which will permit it to slip readily into the mouth of the container. The extracted honey should be of good flavor and exceptionally clean and clear. This is a picture package—the comb is the picture; the extracted honey and an attractive glass container, frame it.

## Cut Comb Honey

Cut comb honey is bulk comb honey cut into pieces varying in size from the 2-ounce individual serving to larger ones weighing nearly a pound. The pieces of cut comb are drained on screened trays in a warm room for 24 hours, or they are placed in small screen baskets and drained by centrifugal force in an extractor. The pieces are then wrapped in cellophane and placed in cartons of various styles with suitable labels (Fig. 185).

## Disposal of Partially Filled Combs

No matter how careful the management has been, there are always some combs unsuitable to use. These are sorted into lots of partially filled combs, unfilled combs, and foundation. Partially filled combs are cut from the frames and the combs mashed to allow the honey to drain from them. The remaining honey and beeswax can be handled in a manner similar to the way cappings are handled. The empty combs and foundation should be stored in a basement or a warm room as alternating heat and cold will cause them to crack and break. The supers containing them should be stacked tightly and fumigated to prevent damage by wax-moth larvae (see Chapter XXIII, "Diseases and Enemies of the Honey Bee").

# XIV. *The Overwintering of Productive Colonies*

BY C. L. FARRAR*

THE honey-bee colony that is allowed to develop without restriction has a remarkable capacity to adapt itself to great extremes in climatic conditions, if its hive is amply provisioned with honey and pollen. A colony whose development is restricted by management will not have a normal population.

Langstroth[1] summarized his ideas on wintering very effectively when he wrote:

> If the colonies are strong in numbers and stores, have upward ventilation, easy communication from comb to comb, and water when needed—and all the hive entrances are sheltered from piercing winds, they have all the conditions essential to wintering successfully in the open air.

That Langstroth understood the basic problems will become evident in the following considerations of the winter cluster, the causes of winter loss, and the principles of wintering.

The honey-bee colony should be viewed as a living organism having continuous life, although the individual bees which make up the colony are continually changing. The beekeeper needs to concern himself with the condition, function, and requirements of the colony, not of the individuals that make up the colony.

The custom of dividing the management program into seasonal periods—spring management, swarm control, honey production, fall management, and wintering—centers too much attention on the individual bees and not enough on the colony as a living organism. Since the colony is the producing unit, it is often better management to wear out the individuals in developing strong colonies rather than to try to save them for some specified time. It is rapidly being recognized that management directed toward meeting all optimum requirements of the colony, regard-

---

*Clayton L. Farrar, Ph. D. Apiculturist in charge, North Central States Bee Culture Laboratory, U. S. Department of Agriculture, maintained in co-operation with the University of Wisconsin; also professor, Department of Economic Entomology, University of Wisconsin. Specialist in the study of bee behavior and seasonal changes in the honey-bee colony.

[1]Langstroth, L. L. 1859–71. *A Practical Treatise on the Hive and the Honeybee.* 3d ed. Philadelphia, Pa. J. B. Lippincott & Co. p. 346. (Also 4th ed. 1876–84. p. 346.)

less of the time of year, will provide the largest population of worker bees for the production of surplus honey and wax, or for the pollination of important crops.

Honey bees are highly socialized in their colony organization, and they possess fixed instincts. Successful management must be based upon an understanding of this organization and the behavior or instincts which govern the work of the colony. From the colony standpoint, we have only to differentiate between the productive and the nonproductive seasons, or between the season of growing plant life and that of dormant plant life. The colony produces all it can during the growing season in order to have food when plant life is dormant. By skillful management, the beekeeper can suppress the reproductive instinct of the colony, namely, swarming, and stimulate the storing instinct.

The colony is active throughout the year, but the type or rate of activity is influenced by climatic factors and the available food supply. Under favorable environment the overwintered colony consists of 20 to 30 thousand bees when flowers begin to furnish pollen in the spring; it then increases by expanding brood rearing to a maximum of 50 to 60 thousand bees. The maximum population is limited by the number of eggs the queen can lay, the time required to develop from the egg to the adult, and the length of life of the adult. As plant life approaches dormancy, brood rearing and field activity decline until they cease entirely. The population decreases rapidly in the early fall until only bees less than 4 to 6 weeks old remain at the end of brood emergence. The normal colony has a population of approximately 30 thousand bees to form the winter cluster. Because they have engaged in little or no brood rearing, these are physiologically young bees capable of living several months, compared with an average life of 5 weeks under summer conditions. The rearing of brood shortens the life of bees more than any other activity.

## The Winter Cluster

### Response to Temperature

When the air temperature falls below a certain point, the bees cluster together to generate and conserve heat. This clustering temperature was determined by Phillips and Demuth[2] to be approximately 57° F. Since that time winter-cluster temperatures have been studied by a number of investigators. While no one has ever recorded a temperature below 57° in the active center of a normal colony, it is now known that all the bees do not become a part of the cluster until the air temperature is approximately 43° to 46°.

The cluster is formed by a grouping together of all the bees to fill the empty combs and spaces between combs into a more or less compact,

[2]Phillips, E. F. and George S. Demuth. 1914. The temperature of the honeybee cluster in winter. *U.S.D.A. Bull.* 93.

spherical mass (Figs. 186, 187). The bees on the surface form an insulating shell varying in depth from 1 to 3 inches while the bees within, which are much less compact, generate heat through metabolic processes. An inner temperature is produced which permits heat to be conducted to the surface bees so that their temperature will not fall below 43° to 46° F. As the outside temperature falls, the cluster draws together, decreasing its size, and, therefore, reducing the surface exposed to heat radiation. This contraction of the cluster concentrates more bees within to generate heat. Conversely, the cluster expands as the air temperature rises. The temperature of the periphery of the cluster is fairly constant at about 43° to 46°, but within the heat-producing center (not necessarily the geometrical center) the temperature rises as the outside temperature decreases. The contraction or expansion of the cluster, however, is the principal mechanism used by the bees in maintaining a favorable environment under winter conditions.

At a given low external temperature, small clusters tend to maintain higher inner temperatures than those of large clusters. As the winter season progresses, the cluster temperature rises until it reaches a brood-rearing temperature of 93° to 96° F. some time in January or early in February. This seasonal increase may be due to long confinement, accumulation of feces, or possibly to aging of the bees. When brood-rearing temperatures are reached, the queen commences to lay and brood rearing will continue from then on if pollen is available.

## Age of Bees

By marking most of the bees emerging during the last 4 to 6 weeks in the fall, it has been determined that the small daily mortality during the broodless period will be represented by bees of all ages in proportion to their number. Since the daily rate of brood rearing decreases during the fall, the number of bees in any age group making up the winter cluster varies over wide limits. A bee emerging on October 1 is just as likely to die on January 1, or on any other day, as one emerging September 1. Winter clusters that had been killed with cyanide showed bees of all ages to be distributed at random throughout the cluster. Although the bees making up the broodless winter cluster vary in age as measured by time, they apparently are of a similar physiological age.

The majority of bees, taken daily from the bottom boards of hives containing overwintering colonies, revived when taken into a warm room and contained food in their honey stomachs. This loss seldom totaled more than 2 to 5 thousand bees during a 3-month broodless period, which is not serious for colonies with approximately 30 thousand bees. The bees that were lost probably became chilled because they failed to accompany a contracting cluster. For additional information concerning the life and habits of bees, see Chapter III, "The Honey-Bee Colony—Life History," and Chapter IV, "Activities of Honey Bees."

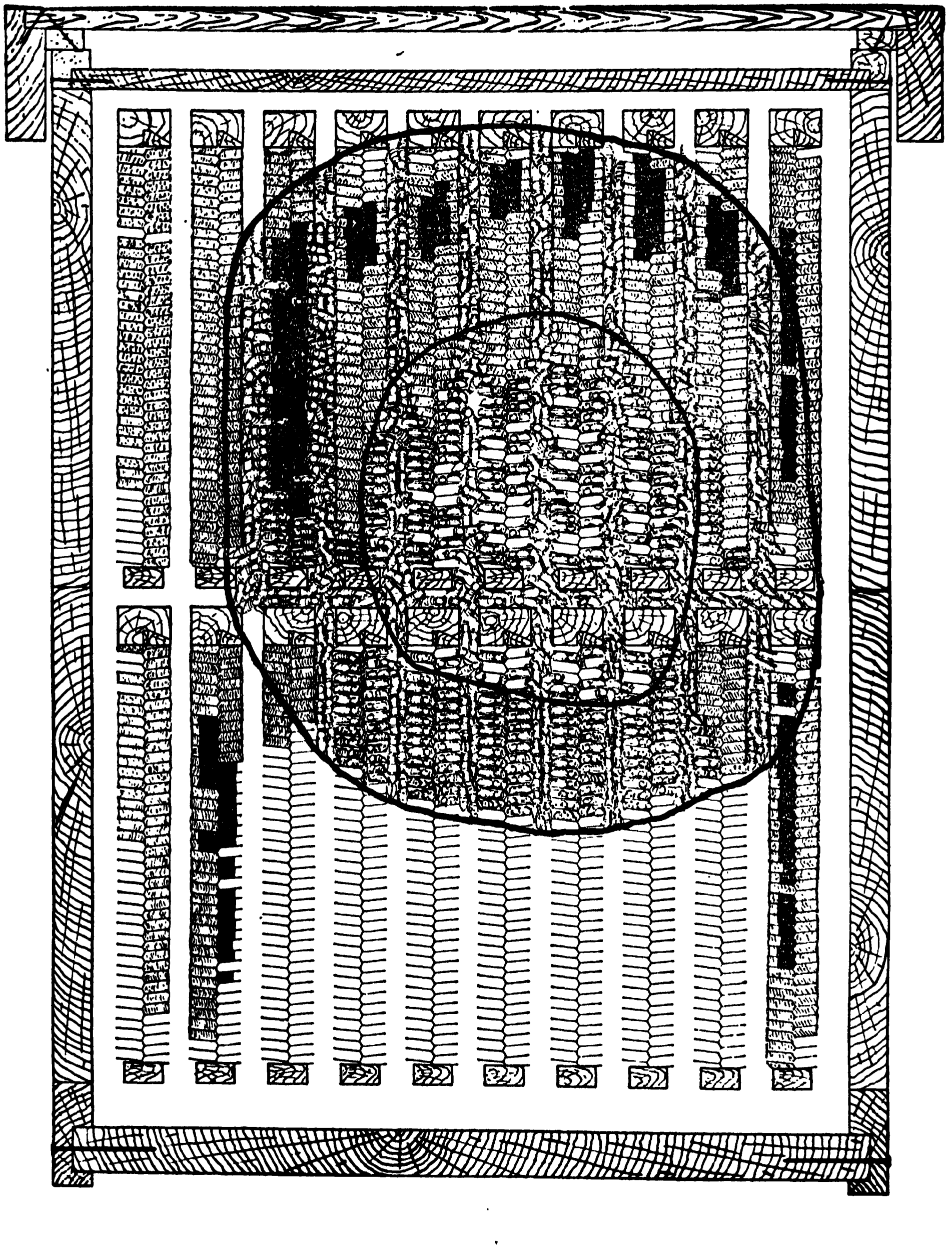


FIGURE 186. Diagram of the winter cluster through the center of the hive, based upon an examination of several colonies. They were killed when the temperature was approximately 0° F. during the latter part of December and before brood rearing had started. The cluster covers 20 to 30 pounds of reserve stores. The much greater concentration of bees in the periphery demarks the insulating shell from the active center. The dark bands of pollen covered with honey indicate an accumulated reserve before the honeyflow. The pollen shown illustrates the optimum reserve more than the quantities found in the average colony. (*Photo courtesy Division of Bee Culture*)

FIGURE 187. Photograph of a winter cluster killed during March when the temperature was 6° F. Because more bees can occupy a given space between combs as honey is consumed, this cluster has contracted into the upper hive body. Approximately one-third of the bees fell off the combs when they were separated, particularly from areas of sealed honey, but the cluster limits have been marked where necessary. On certain frames, the greater concentration of bees forming the insulating shell is plainly evident. The bees shown are those on the side of each frame facing the center of the hive. The two lower combs are from the outside, while the two upper combs are from the center. (*Photo courtesy Division of Bee Culture*)

### Theories Pertaining to the Winter Cluster

Hive protection has long been considered a requisite for wintering honey-bee colonies. Protection has been provided by placing colonies in cellars for 4 to 5 months or by insulating the hives out of doors. The purpose of protection, in whatever its form, was to reduce the cluster activity and thereby conserve bee energy and honey stores. Thus the bees in the winter cluster would live longer, and would still be physiologically young in the spring and capable of rearing large numbers of young bees when pollen and nectar became available. Disturbances caused by fluctuating temperatures, opening of the hive, accumulation of indigestible materials from honeys of low quality, and other means were believed to be responsible for winter losses.

Many organized experiments and thousands of practical tests have been made to test this theory of conservation of energy, but the results have not been consistent. Winter losses continue to tax the resources of the beekeeping industry, because rarely have all the factors been satisfied which are essential to efficient wintering. In the last 20 years there has been a gradual change in winter practices in northern regions. Where colonies were formerly wintered in cellars, they are now wintered out of doors; heavy packing has been reduced to light packing or to wrapping for wind protection, and finally to no special hive protection. Changes in colony standards and food requirements for efficient wintering have paralleled this transition in methods.

Packing fails to conserve the energy of the bees because the winter cluster does not attempt to heat the inside of the hive. An intensive study

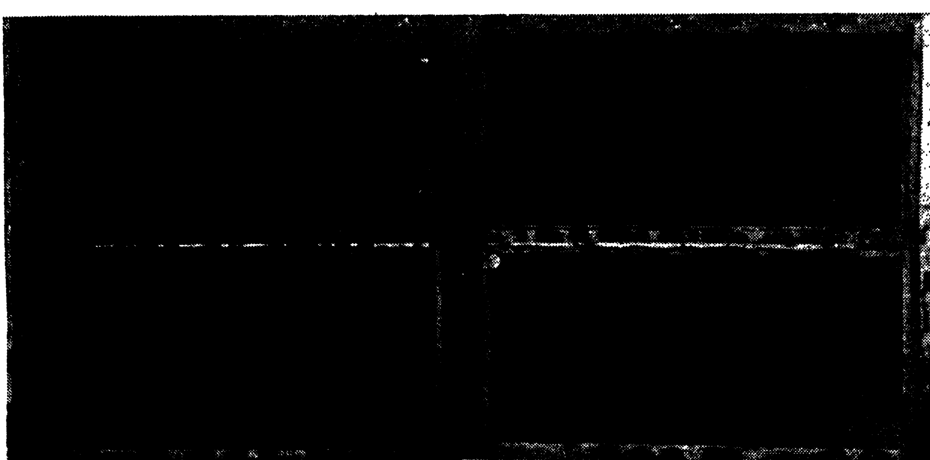


Figure 188. The brood nest from a colony wintered in a three-story unprotected hive photographed on February 10. The brood pattern in two of the combs clearly shows that brood rearing must have begun 30 to 40 days earlier, or soon after January 1. The previous fall, this colony had 9 pounds of bees, 400 square inches of reserve pollen, and an abundance of honey. (*Photo courtesy Division of Bee Culture*)

of the cluster and hive temperatures was made by the writer at Massachusetts State College between 1929 and 1931. Colonies in single-walled hives were compared with those in double-walled hives and with those protected by extreme degrees of hive insulation. Several hundred thousand temperatures were recorded for normal colonies in two-story hives equipped with 118 or more thermocouples. The use of many thermocouples distributed throughout two-story hives established the fact that air temperatures surrounding the cluster approach the outside temperature during a protracted cold period, regardless of the degree of hive insulation. The hive entrance, reduced for winter, is still large enough to permit air currents to dissipate the small amount of heat radiated from the cluster surface.

During the period when emphasis was placed on hive protection, it was assumed that the cluster formed below but in contact with the honey. The cluster was not thought capable of maintaining favorable temperatures while enveloping combs of honey. It was reasoned, therefore, that insulation would permit the cluster to maintain a hive temperature which would allow the cluster to move upward as honey was consumed.

After it was established that insulation did not enable the cluster to maintain a hive temperature comparable with the minimum required by the bees, colonies in both insulated and single-walled hives were examined under winter conditions to observe their organization and activity. By killing colonies while they were tightly clustered it was found that, even when the outside temperature was near zero, first-class colonies often covered 15 to 30 pounds of honey. Colonies will not cluster on sealed combs of honey unless there is an area 3 to 5 inches or more in diameter which is free of honey; neither will they envelop any large area of honey stored in new combs in which brood has not been reared. The space between sets of combs in hives of more than one story may frequently enlarge the open active center, permitting greater movement of bees in the heat-producing area of the cluster. It is possible that a three-story hive with slightly shallower frames would increase this advantage.

The viewpoint that winter brood rearing is normal was untenable under the conservation-of-energy theory. The presence of brood during the winter months was considered detrimental and evidence of poor wintering. Such unseasonable brood rearing was considered to be due to insufficient hive insulation, low-quality stores, or to some abnormal disturbance.

As long ago as 1852, Langstroth,[3] observed brood in all stages on February 5, and demonstrated that pollen was necessary for continued brood rearing. Work done by the United States Department of Agriculture since 1932 has shown conclusively that winter brood rearing is both normal and beneficial to the colony (Fig. 188). At no time have any

[3]Langstroth, L. L. 1859. *A Practical Treatise on the Hive and the Honeybee.* 3d ed. New York, N. Y. A. O. Moore & Co. p. 81.

harmful effects been observed from the inability of newly emerged bees to have an immediate flight when reared during the winter. The size and quality of surviving populations have been found to be directly proportional to the quantity of reserve pollen within reach of the winter cluster.

To provide every colony with optimum pollen reserves presents a major problem in apiary management. However, the more recent practice of feeding trapped pollen supplemented with expeller-processed soybean flour provides a means of regulating the early development of colonies. Pollen reserves may be out of reach of the cluster during low temperatures. Supplemented pollen cakes placed over the center of the cluster permit the timing of brood rearing independent of climatic conditions.

## Winter Losses

Winter losses usually are reported as the percentage of colonies that die out. Beekeepers seldom fully recognize that a much greater loss results from colonies that survive in weakened condition and consequently with greatly reduced productive capacity. No other branch of agriculture could survive if it continued to suffer the winter losses experienced by the beekeeping industry. The tremendous reproductive power of bees makes this possible, but the economic loss is not minimized in the least.

Winter losses result from starvation, weak colonies, inadequate supplies of pollen, Nosema disease, and queenlessness. These causes may operate separately or collectively either to kill the colony or to reduce its productive strength. Climatic conditions have only an indirect effect on winter losses. The type of climate will influence the standards that must be met to insure the successful overwintering of a colony, but it is doubtful whether any region favorable for commercial honey production has such severe winters that normal, healthy colonies cannot survive in good condition if properly provisioned with honey and pollen.

### Starvation

Many colonies are lost from starvation because too little honey is left in the fall. Good colonies in most northern regions consume, on an average, 50 to 55 pounds of honey from the time brood rearing ceases in the fall until sufficient nectar is gathered in the spring to support the colony. Because the best colonies use more than the average, a minimum of 60 pounds should be present in late fall (Fig. 189). Additional honey may be required by exceptional colonies in the spring, or by all colonies when the weather is unfavorable for nectar secretion by soft maples, willows, fruit trees, dandelions, and other spring flowers. The practice of providing 80 to 90 pounds of honey in the fall reduces labor cost and insures adequate food under practically all conditions.

The strength of overwintered colonies is directly proportional to the amount of honey consumed. Honey consumed by good colonies in rearing

bees is more valuable than the same amount of honey sold for human consumption. Populous colonies will replace the honey used in winter during spring honeyflows, when small colonies gather only enough to meet their daily needs. Furthermore, these large colonies will produce from two to ten times as much surplus honey as the retarded colonies. Honey, which is not consumed in winter, will reduce the amount the colonies must store to provide the next season's reserve.

The cluster must be able to encompass honey throughout the winter. It will form in the top of the hive when there are dark brood combs containing a small open center that is free of honey, but it will avoid a top chamber containing all new white combs, or old dark combs if the latter are filled solidly with honey. The top chamber of a Langstroth ten-frame hive should contain 45 pounds of honey at the close of brood rearing. This amount represents seven or eight full combs of sealed honey and the remaining combs two-thirds or one-half full. The chamber below should have 20 to 30 pounds of reserve honey, which the bees will move in the fall or spring under favorable temperatures. Still larger food reserves are desirable some seasons. It is, therefore, good practice to provide an additional 20 to 30 pounds in a third chamber underneath for the bees to move during the spring.

Too little honey in the top chamber may allow the colony to starve even though there is plenty of honey in the chamber below. A small cluster may become stranded on one side of the hive and starve with

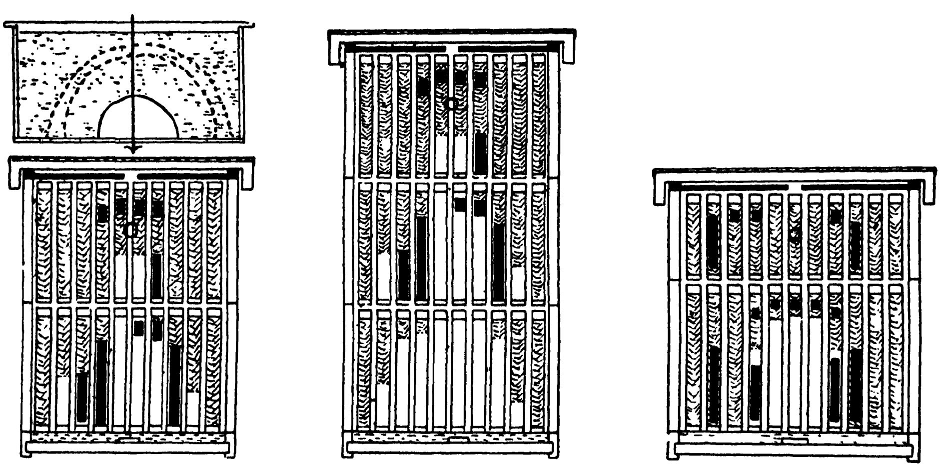


FIGURE 189. Diagrams of the most favorable organization of honey and pollen reserves for Langstroth and Modified Dadant hives at the close of brood rearing. The arrow drawn through the single frame above the two-story Langstroth hive indicates the position of the section through the three hives. The auger hole in the top chambers and the entrance cleats would, of course, be in the front of the hives. The dark bands illustrating pollen indicate optimum rather than average reserves. By interchanging hive bodies, pollen reserves accumulated early in the season may be covered over with sealed honey. (*Photo courtesy Division of Bee Culture*)

honey on the opposite side. On rare occasions when the cluster fails to form in the top chamber because it contains new combs or dark combs that are solid with honey, the colony may starve with honey above if there is brood to hold the cluster in the lower chamber.

The beekeeper may misjudge the amount of reserve honey available for winter. Heavy brood rearing after the main honeyflow and the failure of fall flowers to secrete nectar may leave colonies inadequately provisioned. This danger always should be anticipated and sufficient surplus left in the hive after the main honeyflow to provide each colony with 120 pounds until the end of the season. The last of the crop may be removed at the close of brood rearing, after a colony's winter food reserve is assured. When the beekeeper provides the colony's needs, even though more equipment is required, he assures himself of much larger honey crops from which to obtain his profits.

The three-story Langstroth hive for year-round management provides a means of storing plenty of reserve honey for the colony (Fig. 190). In localities that provide good flows from plants producing off-flavored honey, special manipulations may be needed to concentrate such honey in the minimum number of combs for winter feed. Where disease is not a problem, this honey may be removed and stored until after the main honeyflow and then returned to the colonies for reserve food.

It is sometimes impossible to determine accurately each colony's need for reserve food. An occasional colony headed by an exceptional queen and containing large pollen reserves may become so strong through winter brood rearing as to require much more honey than the average good colony.

Robbing in an apiary may unbalance the stores between hives. There are two forms of robbing. One is always recognized by beekeepers because of the tremendous bee activity and the complete destruction of the robbed colony, unless safeguards are used immediately. The other is described as progressive robbing. The bees from one colony enter another hive to fill up with honey and return to their own without antagonizing the robbed colony or destroying it as long as it has food. Observations have shown that individual colonies subjected to progressive robbing sometimes require twice the normal amount of honey. Progressive robbing probably is fairly common and often accounts for the difference in apparent food consumption between otherwise equivalent colonies.

## Weak Colonies

Weak colonies require less honey to survive than strong colonies, but they use more honey for the number of bees present. Small clusters are at a serious disadvantage in cold weather because of the low ratio between bees in the center generating heat and those in the insulating shell. The small cluster is unable to maintain brood-rearing temperatures over a sufficient area to rear the young bees necessary for replacing those worn

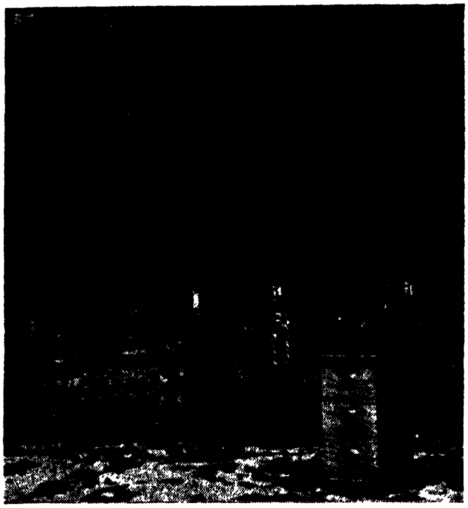


FIGURE 190. An apiary overwintered in three-story hives. (*Photo courtesy Division of Bee Culture*)

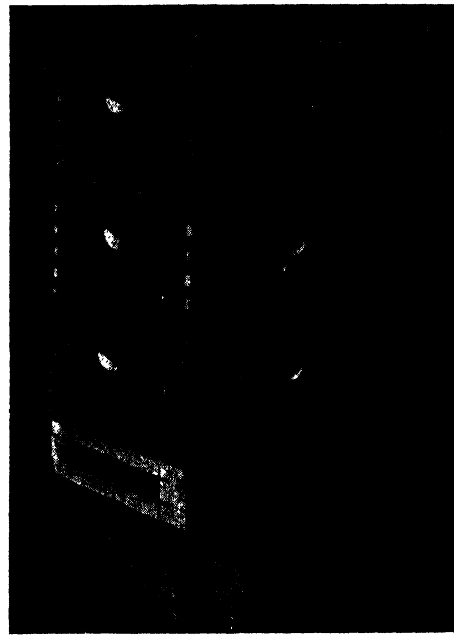


FIGURE 191. Hive equipped with a pollen trap consisting essentially of a grid made from 5-mesh hardware cloth, a pollen tray with an 8-mesh cover, and a shield for attachment. The ventilating rim with screened openings has value during warm weather in preventing the bees from clustering over the grid. (*Photo courtesy Division of Bee Culture*)

out, or lost from chilling or disease. Small healthy colonies sometimes survive under severe climatic conditions but, because they seldom gain in strength during the winter, their productive capacity is low the next season.

Weak colonies result from restricted brood rearing during the summer. This restriction may be brought about by the use of small hives, crowded brood chambers due to certain manipulative practices or the lack of any manipulation, a scarcity of pollen, poor queens, queenlessness, disease, and/or poisoning either of insecticidal or plant origin.

A single brood chamber is too small to allow for optimum brood production during late summer unless special manipulations are used to keep it free of excess honey and pollen. In an unmanipulated two-story brood chamber, brood rearing may be restricted by the use of a queen excluder or by top-supering if there is a substantial honeyflow at that time. If the honeyflow ends in midsummer this restriction may be beneficial, for there will be more honey in the brood chambers for winter. The restricted colony then will expand brood rearing sufficiently to develop a normal winter cluster, if it has a good queen and pollen is available. Without a concentrated honey reserve the colony would require additional feed for winter. Because the exact time or duration of honeyflows cannot be predicted, unrestricted brood rearing is more likely to

provide populations that will yield maximum crops and normal clusters for winter. Unrestricted brood rearing requires more hive equipment to accommodate the colony and to provide space for reserve honey.

Weak colonies frequently are due to poor queens. The nonproductive queen lays too few eggs to provide a normal cluster. Even if a colony with a poor queen survives the winter, it has little chance of building a productive population. The colony that loses its queen late in summer may be unable to build a normal population for winter because of the break in brood rearing. However, vigorous young queens usually lay later in the fall, permitting the colony to gain strength. If such colonies have adequate honey and pollen reserves, they may survive in excellent condition.

A dearth of pollen during late summer will result in weak colonies for winter. Colonies vary in the amount of reserve pollen they accumulate during the summer; those with pollen reserves will continue brood rearing during dearth periods. During periods of a pollen scarcity certain colonies frequently find pollen sources that are not worked by all colonies in the apiary; under such conditions the fall population of colonies may vary tremendously.

### Spring Dwindling Due to Insufficient Pollen

Insufficient pollen to support normal brood rearing during late winter and early spring is the basic cause of spring dwindling in otherwise normal, healthy populations. The dwindling of populations in the spring too often is attributed to seasonal rather than to colony conditions. Colonies that are provisioned with plenty of pollen in a position available to the winter cluster will replace their fall populations with young bees and have a large brood nest when the first pollen becomes available from the field. Such colonies increase their populations rapidly, while colonies wintered without pollen dwindle for 3 to 6 weeks after fresh pollen becomes available, or until the emergence of brood exceeds the mortality of the old bees. Colonies that benefit from winter brood rearing frequently store more honey during the dandelion or other early flows than they consume in winter, while colonies wintered without pollen scarcely gather enough nectar to meet their daily food requirements.

Surveys of fall pollen reserves and normal colony requirements have been made in the Intermountain States, the North Central States, the Pacific Coast States, and in the package-bee producing areas in the South. In all these regions pollen reserves have been found inadequate for optimum colony development. The pollen problem is more acute in some localities and in some seasons than in others, depending on plant sources, seasonal conditions, and type of colony management.

In most northern beekeeping areas, colonies should enter the winter period with the equivalent of three to five well-filled pollen combs. A reserve of approximately 500 square inches (both sides of the comb estimated separately) of cells containing pollen is desirable for each colony.

The amount of reserve pollen in the colonies of most apiaries may vary from none to a few hundred square inches. Few apiaries will average more than 100 to 300 square inches per colony although an occasional colony may exceed 1,000 square inches. The occasional colony with an excess of pollen causes many beekeepers to conclude that they have no pollen problem.

Pollen reserves must be located within the cluster if they are to be utilized in winter brood production. It is impractical, however, to have 500 square inches of pollen located in the top chamber because too little room is left for honey stores. One or two good pollen combs in the top are advantageous, particularly if they also contain honey. Several combs containing bands of 30 to 60 square inches of pollen covered with honey are ideal, but the bulk of the pollen should be near the center of the chamber just below. Except under extremely low temperatures, strong colonies will occupy two chambers so that in the spring the pollen in the lower combs will become available for brood rearing.

Pollen collection, like honey storage, is proportional to colony strength during the producing periods. The accumulation of pollen reserves depends upon the amount collected and the amount consumed in brood rearing. Colonies that have failing queens or are queenless when there is an abundance of pollen in the field accumulate the largest reserves.

Some adjustments in pollen reserves between colonies may be made profitably, unless a disease problem precludes the exchange of equipment. If a super of dark brood combs is placed beneath the active brood nest during periods of heavy pollen collection, the bees will store pollen there. If this super can then be raised above the brood nest during a good honeyflow, the pollen will be covered with sealed honey, thus preserving it indefinitely.

There is no satisfactory substitute for pollen, but a pollen deficiency can be largely overcome by feeding trapped pollen (Fig. 191) supplemented with expeller-processed soybean flour (see "Pollen Supplements" in this chapter).

## Winter Dysentery and Nosema Disease

Dysentery sometimes causes substantial losses among colonies wintered in the North where the bees are confined to the hive for months at a time. The presence of dysentery indicates an unhealthy condition of the bees, and few affected colonies survive to produce a profitable crop. Colonies are considered to suffer from dysentery whenever the bees discharge feces within the hive.

Dysentery usually has been considered to be due to the excessive accumulation of indigestible materials during long confinement in the winter cluster. Dysentery also has been attributed to excessive moisture, either in the honey stores or in the hive atmosphere, which prevents the bees from excreting moisture rapidly enough to maintain a favorable

balance in their bodies. Recent studies, however, strongly indicate a pathological condition, due to Nosema disease, to be the primary cause of dysentery. Nosema spores have been found in the majority of bees and in the feces discharged within the hive of every colony suffering from dysentery examined since the winter of 1940–41 (see reference 1942 at end of chapter).

The accumulation of indigestible materials was presumed to be aggravated by unnecessary activity of the cluster resulting from insufficient hive protection, winter brood rearing, and low-quality honeys, namely, those high in dextrin and resins. Experimental tests and commercial beekeeping practices, however, have demonstrated that practically all well-ripened honeys are satisfactory for winter food if present in sufficient quantity.

Colonies have been wintered successfully at Madison, Wisconsin, in skeleton hives providing only a framework to support the two sets of combs and a cover. These colonies lacked even the protection of single-walled hives.

Colonies have been wintered successfully at Laramie, Wyoming, when provided with 25 pounds of honeydew stores that contained 12 to 13 per cent dextrin. Although inferior to equivalent colonies that had honey, when supplied with pollen reserves they were superior to colonies on honey without pollen. Only two out of eight colonies wintered on honeydew stores suffered from dysentery, and it is probably a safe assumption, based upon recent studies, that these were heavily infected with Nosema. At Madison, Wisconsin, during the winter of 1944–45, additional tests on honeydew stores verified these results and assumptions.

The unfavorable moisture balance was presumed to result from poorly ripened stores, granulation of stores, inadequate hive ventilation, high humidity, and excessive activity of the winter cluster. The moisture content of most honey stores in the North Central States is at least 5 per cent higher than in drier regions, such as the Intermountain States; yet good colonies survive the winter in similar condition in both. Studies by Woodrow[4] at Laramie, using caged bees, showed that high humidity was unfavorable to long life and that the bees developed a form of dysentery. It is unlikely, however, that the results are directly applicable to conditions present in normal colonies.

Nosema disease, caused by the protozoan, *Nosema apis,* has been recognized as a disease of the adult bees since the organism was named by Zander[5] in 1909. The disease is known to be widely distributed, but it has been considered relatively unimportant although occasionally causing loss of bees for a month or two in the spring. New attention was centered on the problem at Madison, in 1940, because of the adverse behavior of

---

[4]Woodrow, A. W. 1935. Some effects of relative humidity on the length of life and food consumption of honeybees. *Jour. Econ. Ent.* 28:565–568.

[5]Zander, Enoch. 1909. Tierische Parasiten als Krankheitserreger bei der Biene. *Leipziger Bienenzeitung* Jahrg. 24, Heft. 10, pp. 147–150, Oct.; and Heft. 11, pp. 164–166, Nov.

colonies maintained in a greenhouse for testing the brood-rearing value of pollen and supplements. Colonies that reared brood normally for 6 weeks stopped feeding brood as soon as most of their bees became infected with Nosema. Then, when observations were made for Nosema in colonies overwintered out of doors, a considerable number were found weakened by the disease. Spring dwindling may result from Nosema disease because infected bees do not support normal brood rearing and their own lives are materially shortened.

When the percentage of Nosema-infected bees in the colony is high at the beginning of winter, dysentery will become evident after a relatively short period of confinement, and the colony has little chance of survival. Even with a low incidence of the disease in the fall, long periods of confinement increase the infection and serious loss may result. Whenever the weather is such that the bees are stimulated to take cleansing flights, many of these infected bees drop to the snow and are lost, thus reducing the infection potential in the colony.

Nosema disease seems to be the most certain of the three suggested causes of winter dysentery and infected bees very likely increase the activity of the cluster. If the quality of stores is poor, the bees consume more honey and thus accumulate more indigestible material. Because the water metabolism of infected bees is probably not normal, it is possible that both the accumulation of indigestible material and unfavorable moisture conditions could hasten a condition of dysentery in the infected colony.

The infection of queens with Nosema has recently been shown to be responsible for considerable supersedure in package colonies. Circumstantial evidence has indicated that overwintered colonies surviving in a queenless condition, or with virgin queens, may have lost their laying queen from Nosema. The infection of the queen, however, is one of chance, inasmuch as some colonies may lose all but a handful of worker bees from Nosema, and yet the queen may escape infection.

Although Nosema infection and a lack of pollen are major causes of spring dwindling, other secondary causes may prove equally damaging to individual colonies or to an entire apiary in certain locations. These include failing queens, partial starvation of the cluster, severe drifting, arsenical poisoning, plant poisoning, sacbrood, European foulbrood, American foulbrood, and diseases of adult bees (see Chapter XXIII, "Diseases and Enemies of the Honey Bee").

## Colony Standards for Overwintering Productive Colonies

The consideration of the colony as a single organic unit, and an understanding of the formation and activity of the winter cluster, as well as the causes of winter losses, predicate definite colony standards for successful wintering. The problem of management is not how or where, but what kind of colonies are wintered.

The colony requirements during the nonproductive period of winter must be anticipated during the productive period when growing plants supply pollen and nectar. The so-called fall and winter management becomes principally a problem of making adjustments where colonies fall below optimum standards.

The normal productive colony should meet the following standards at the close of brood rearing in the fall and just prior to dandelion or similar bloom in the spring. The two-story Langstroth hive should have a minimum gross weight of 130 pounds in the fall to insure 60 pounds or more of honey; the three-story hive provisioned with 90 pounds of honey will weigh 180 pounds. In the case of the Modified Dadant hive with one super used as a food chamber, a gross weight of 140 to 170 pounds will provide food reserves within the range of 60 to 90 pounds.

### Fall Condition at Close of Brood Rearing

(1) A productive queen
(2) Bees covering 20 combs in a normally provisioned hive—8 to 10 pounds of bees
(3) 45 pounds of honey in top chamber in dark brood combs
(4) 15 to 30 pounds of honey in lower chamber
(5) 500 square inches of pollen divided between both chambers (this amount is desirable but seldom attained)
(6) Reduced lower entrance and 1-inch auger hole in top chamber
(7) Protection from wind
(8) Maximum exposure to sunshine
(9) Well-drained location

### Spring Condition at the Beginning of Dandelion or Similar Bloom

(1) A productive queen
(2) 10 to 20 frames of bees—8 to 10 pounds
(3) 6 to 10 frames of brood
(4) 15 pounds or more of reserve honey
(5) Continuous supply of pollen or pollen supplement
(6) Entrances adequate for free flight of bees
(7) Hive organization permitting upward expansion of the brood nest
(8) Storage space adequate for honeyflow

Colonies in three-story Langstroth, or one and one-half story Modified Dadant, hives containing 90 pounds of honey are even better prepared for winter than two-story hives provided with a minimum of 60 pounds. The reader may ask why, in the literature on wintering, the recommended food reserve has increased from 20 or 30 pounds to 45, 50, 60, or 90 pounds. The hazards of wintering bees are reduced by increasing the food reserves; spring feeding is avoided; and larger hives, stronger colonies, and improved methods make it necessary to leave more honey. Larger and more certain crops have been the direct result of these changes. Colonies

that consume less than 50 pounds, between the end of one productive season and the beginning of the next, seldom can be considered first-class colonies. It should be recognized, however, that gains by strong colonies from early nectar sources, such as soft maple and willow, may obscure the true winter requirement. These early sources cannot be depended upon; therefore, maximum honey stores must be provided to insure productive colonies.

## Location of the Apiary

Apiary locations should be chosen which provide a maximum protection from prevailing winds. A sheltered location is desirable both under low temperatures when the bees are clustered and at temperatures when they can fly. Snow coverage is not harmful, even if colonies become buried in deep drifts for weeks at a time, and provides protection from the wind. Sunlight is beneficial, especially midday sunshine on the hive entrance. Sunshine on the hive may allow an expansion or shift of the cluster, while the sun shining on an upper entrance may allow the bees a brief flight. The hives should face south whenever possible. For additional information, see Chapter VIII entitled "The Apiary."

## Hive Entrances

To winter a colony in the best possible condition, the bottom-board entrance should be reduced with a cleat to an opening 3/8 by 1 or 2 inches, and a 1-inch auger hole should be provided just below the handhold in the front of the top chamber. The upper auger-hole entrance is rapidly being adopted by beekeepers, and it appears to have considerable merit. It has proved beneficial under some circumstances, and at no time has it been found detrimental. Bees will fly from the upper entrance at times when they would be deprived of flights if they were obliged to use the lower entrance. If the lower entrance becomes temporarily blocked with ice, snow, litter or dead bees, the bees still can fly whenever they desire. This is particularly important when hives have been covered with deep snow (Fig. 192). The top may be exposed to sunshine a week or more before the lower entrance is open, and the colony without an upper entrance may be lost or may suffer severely because the bees are confined. The question as to whether or not the upper auger hole insures a drier hive atmosphere awaits scientific investigation. The bees prefer them in both winter and summer, which alone justifies their use. They may be used in all brood chambers, but only the hole in the upper one is left open in winter.

The lower entrance tends to prevent the growth of moulds on the lower combs which are not covered by the bees. When hives are closed tightly below, the accumulation of dead bees and debris holds moisture.

The hive should tilt slightly forward and have an entrance large enough to allow drainage of water from the bottom board and the removal of dead bees. The dead bees will dry up considerably even when it is too cool for the colony to clean them out. It is often advisable to place a wire entrance guard over the lower entrance to exclude mice. Hardware cloth, three meshes to the inch, should be used for these guards.

## Hive Packing

The advisability of winter packing depends on the relation between the cost of material and labor for packing and the saving of honey consumed. Packing will not make strong colonies out of those deficient in honey, pollen, or population, or those having a poor queen or a heavy Nosema infection. Surveys of winter losses in commercial apiaries generally show that more unprotected colonies than packed colonies die out, but that death is due primarily to starvation. The percentage of colonies that will survive on a reserve of 50 pounds of honey is higher for packed colonies than for colonies left without packing; on a reserve of 60 pounds the difference is negligible. Strong productive colonies will survive whether or not the hives are protected, if provision is made for all the colonies' internal requirements (Fig. 193).

In addition to conserving some honey stores, packing protects colonies in outapiaries from being pilfered, because the two- or three-story unprotected hives, heavy with honey, present a greater temptation to steal the honey. Packing also protects the hive from weathering during the winter

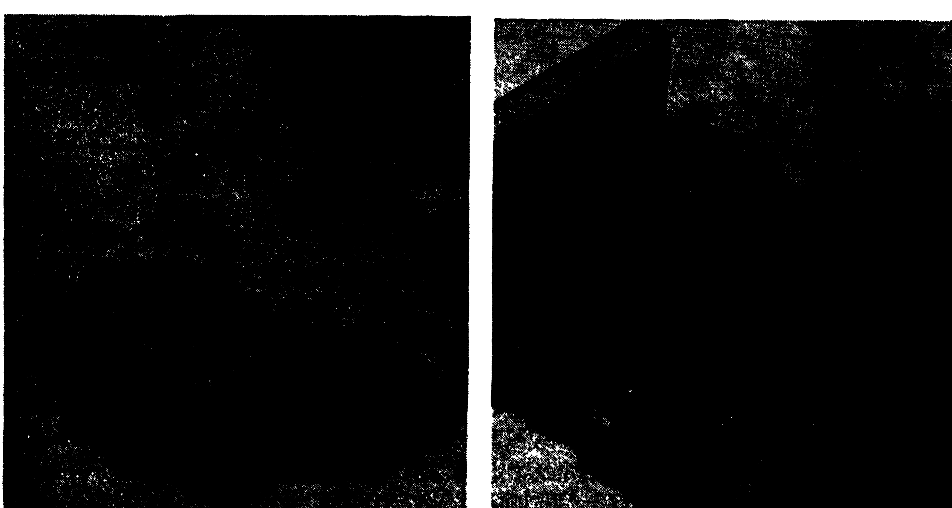


FIGURE 192. A colony that was buried under a snowdrift from January 14 until March 15 when at least 1 ½ feet of snow was removed from the top of the hive. When the cover was removed, the large cluster shown had many newly emerged bees and brood in three frames. (*Photo courtesy Division of Bee Culture*)

FIGURE 193. A three-story colony wintered without hive packing. (*Photo courtesy Division of Bee Culture*)

FIGURE 194. A two-story colony wintered with hive packing. (*Photo courtesy Division of Bee Culture*)

period. The packed colony, on the other hand, is not so easily provisioned with cakes of pollen supplement when pollen reserves are inadequate.

The most economical method of protecting the hive is use of the tar-paper wrap. This method provides excellent protection against the wind, and the black paper absorbs heat from the sun. A good grade of weatherproof paper, such as slater's felt, cut to encircle the hive, is cleated to the bottom board and along the overlap. It is then folded over the inner cover and held in place with the outer cover. Both lower and upper entrances are easily left open with the aid of cleats. The top can be given further protection by using a metal cover permanently insulated with a pad of newspapers, by using a sheet of ½-inch insulating board inside the cover, or by placing a super rim filled with dry insulating material above the inner cover.

Sometimes tar paper is used to make a case around the hive, or a group of hives, to be filled with insulating material (Fig. 194). Paper of sufficient length is then cut to provide for the desired amount of insulation. The lower edge is cleated to the bottom board or hive stand with corner tucks to equalize the case around the hive. A false case consisting of four hinged panels may be set around the hive to shape the paper case while the insulating material is being added. The overlapping ends of the paper can be cemented together with hot asphalt, or, by providing for more overlap, the case may be held together with twine. Dry packing

material, such as leaves, chaff, straw, or planer shavings, is then packed firmly between the hive and the paper. The case is filled uniformly on all sides at once to prevent a lopsided pack.

From 2 to 4 inches of packing should be the maximum used on the front of the hive. The sides, back, and top may be provided with 6 to 8 or more inches. The lighter packing in front enables the colony to respond to sun radiation that may permit the flight of bees or a shift in the position of the cluster. Where the hives are set on stands, the space beneath the bottom boards is usually filled with insulating material first. The paper case may then be cleated to the hive stand instead of to the bottom board, except in front. A small tunnel or tube can be adapted to the auger hole to provide an upper entrance through the packing or, after the lower part of the hive is packed in front, the paper can be tucked in and held with a cleat having a hole that matches the one in the hive. The case is then completely filled, and the false case removed for use in packing the next colony. Top packing is placed either above the metal cover or, with this cover removed, over the inner cover, after the escape hole has been covered with screen. The top edges of the case are folded in and covered with another piece of paper, which is tied in place with twine. If the metal cover has been removed, it may be tied on top to give some protection against damage to the paper.

Hives may be packed in pairs with less labor and material than when packed singly. Some beekeepers pack groups of five to ten hives in a row, but this method often results in drifting of bees between colonies.

The packing should be done early in the fall when the temperature is still high enough for the paper to be handled without cracking. The packing may be removed when the bees begin to collect pollen in the spring, usually during willow bloom.

## Pollen Supplements

Pollen deficiencies may be largely overcome in the spring by feeding cakes of trapped pollen supplemented with soybean flour. Soybean flours produced by the expeller process are superior for pollen supplement to flours refined by the chemical-extraction process. Feeding may be started a month or 6 weeks before pollen is collected from the field and continued through the spring when pollen collection is intermittent.

These cakes are prepared by mixing 1 part dry matter (1 part pollen and 3 parts of expeller-processed soybean flour) and 2 parts sugar sirup (2 parts sugar and 1 part hot water). Dry pollen softens readily in water but not in sugar sirup; therefore, the desired amount of pollen should be added to the water before dissolving the sugar.

Any number of cakes can be prepared using these proportions. For example 32 cakes weighing 1½ pounds each can be made by mixing 4 pounds of dry pollen in 11 pounds of hot water, add 21 pounds of sugar

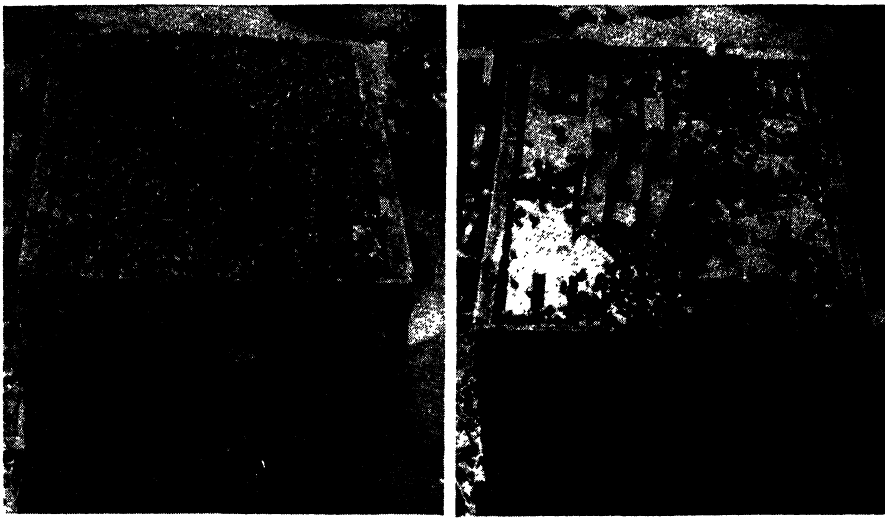


FIGURE 195. Colony feeding on a cake of pollen supplement with soybean flour. The bees practically obscure the wax paper over the cake. The feeding channels are shown after the bees were smoked down, and the cake turned over. (*Photo courtesy Division of Bee Culture*)

and stir until in suspension, finally add 12 pounds of soybean flour and mix until it forms a doughlike paste. This amount is sufficient to produce approximately 120,000 bees, or a pound of bees in each of 32 colonies.

A 1½-pound cake is placed on the top bars directly over the center of the cluster and covered with wax paper to prevent drying (Fig. 195). The inner cover is reversed to provide space for the cake. A new cake should be added before the previous one is entirely consumed, usually at intervals of approximately 10 days. Colonies with five to seven frames of brood may be given 2 to 3 pounds at one time.

When trapped pollen is not available, cakes made with the soybean flour alone may be fed advantageously to colonies having scattered pollen in the combs, to colonies lacking pollen about 10 days prior to spring pollen collection, and in the spring when pollen collection is likely to be intermittent. Soybean cakes are not so effective as those containing pollen, but they do permit more brood to be reared when pollen is scarce.

## Trapping Pollen

Pollen for these cakes must be collected as the bees bring it into the hives, for there is no commercial source of bulk pollen. A pollen trap[6] has been devised which consists of a grid made from 5-mesh hardware cloth over a tray covered with 8-mesh wire cloth (Fig. 196). The bees must pass through this grid as they enter or leave the hive, and most of

[6]Schaefer, C. W. and C. L. Farrar. 1941. The use of pollen traps and pollen supplements in developing honeybee colonies. *U. S. Bur. Ent. & Plant Quar. Circ.* E-531.

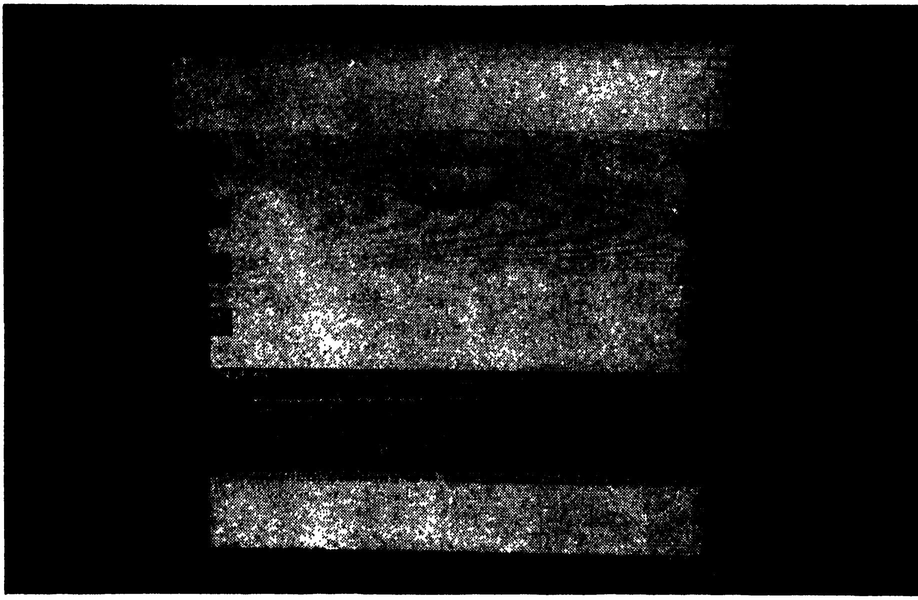


FIGURE 196. Pollen trap showing storm shield, grid, and pollen tray. (*Photo courtesy Carl E. Killion*)

the pollen is scraped from their legs and falls into the tray. The grid is fastened inside the top of a storm shield, which also supports the pollen tray and attaches the complete unit to the hive entrance.

Beekeepers are inventive by nature, so it is not surprising that many types of pollen traps employing these principles are now in use. The important thing is to gather enough pollen to build each colony to full producing strength before the honeyflow, regardless of spring weather conditions. Trapped pollen, when properly dried, can be stored for years in closed containers without appreciable loss in its value for brood rearing. One pound of trapped pollen is not too large a reserve to be maintained for each colony or package, but, like honey reserves, the average requirement may be half this amount. The beekeeper should prepare for the most adverse season rather than the average.

The pollen trays should be emptied every day or two (Fig. 197). For this reason pollen traps cannot be satisfactorily used in outapiaries. The pollen should be thoroughly dried and then stored in a closed container such as a 5-gallon honey can. Pollen may be dried rapidly in quantity in an improvised oven made of a large fiber carton by building in a framework to support cheesecloth trays on which to spread the pollen. Mazda lamps, installed with due precaution against a fire hazard, may be used to supply the heat at the bottom to drive off moisture-laden air through an opening at the top.[7]

[7]Woodrow, A. W. 1947. Drying and storing pollen trapped from honeybee colonies. *Amer. Bee Jour.* 88(3):124–125.

## Wintering Surplus Queens and Double Colonies

Surplus nuclei that have good queens but only three or four frames of bees may be successfully wintered above strong colonies. A screen is placed over the upper brood chamber of the normal colony, and on it is set a single hive body provided with an auger-hole entrance. The nucleus is placed in the center of this body, and six or seven frames of honey and pollen in dark brood combs are added to provide food.

The two clusters will winter in direct contact but separated by the screen. If both the normal colony and the nucleus have auger-hole entrances, some bees from the colony below will drift into the nucleus, and it may be the stronger unit in the spring. To reduce this drifting it is just as well to provide the lower colony with an auger-hole entrance in its bottom chamber instead of the upper. When the normal colony is wintered in three stories, this entrance should be in the middle chamber.

Two full-strength colonies may be wintered by the same method, except that each should have normal honey and pollen reserves. Four

FIGURE 197. Pollen trap with the tray removed showing more than a pound of pollen pellets. The 8-mesh hardware cloth cover for the tray is resting on the storm shield. (*Photo courtesy Division of Bee Culture*)

Langstroth hive bodies are required for these double colonies, and, to minimize drifting, auger-hole entrances should be placed in the bottom chamber of the lower colony and in the top body for the upper colony. Demareed colonies that happen to have two queens, or colonies managed under a two-queen plan, may be wintered as double colonies, if the beekeeper has plenty of reserve honey and pollen and desires increase. Beekeepers who have followed this procedure on a considerable scale believe that the double colonies consume less honey than when they are wintered separately.

## Cellar Wintering

Cellar wintering is no longer recommended, because the majority of beekeepers have found that colonies wintered out of doors with plenty of honey and pollen are stronger in the spring and therefore more productive. Some beekeepers, however, still prefer to winter in cellars because they have considerable money invested in them and they are thoroughly familiar with the problem of cellar wintering. In localities providing late honeyflows, cellar-wintered colonies may be built up to a strength that will permit them to produce a profitable crop.

A word of warning should be given to beekeepers who are accustomed to cellar wintering and desire to try outside wintering. Colonies prepared for cellar wintering, if left outside, will prove disappointing. Much more honey must be provided for the large productive colonies wintered out of doors than for the smaller cellar-wintered units.

## The Relation of Wintering to Productive Management

To provide for the optimum requirements of the normal colony during the nonproductive season, the beekeeper must apply skillful management during the productive season. The strong colony requires more hive space, which must be properly organized for expansion in brood rearing and honey storage, to prevent the colony from swarming. Queens wear out faster in colonies that are provided with pollen or pollen supplements because they rear a larger amount of brood in late winter and early spring. Honeyflows may develop from plants formerly thought to be only of minor importance because colonies were not strong enough to make gains. Temporary increase during spring may be necessary or profitable as a swarm-control measure. However, when the main flow develops it is often more profitable to reunite the increase, because the strong colony will produce more honey for a given number of bees than several small colonies. Such uniting is an efficient method of providing each producing colony with a young queen during the honeyflow.

Colony standards have changed since Langstroth's time, but the principles he outlined cover the requisites of wintering and we need only to

FIGURE 197a. A beautiful location for an apiary. The evergreens provide winter wind protection for the unpacked colonies with upper entrances, the lower entrances being covered by the deep snow. (*Drawing by R. A. Grout after photo by Robert Burke*)

assign the necessary values. A colony "strong in numbers" now means 30 thousand young bees (10 pounds), which represents a normal population of an unrestricted colony. A colony "strong in stores" now has 60 to 90 pounds of honey and 500 square inches of pollen. Although Langstroth recognized the need for pollen, 75 years elapsed before the significance of the pollen supply in controlling colony development was understood. The upward ventilation he recommended has been readopted only recently by the use of auger-hole entrances. Langstroth allowed communication between combs by cutting holes through the center, while today the same objective is accomplished in hives of more than one story by the space between the two sets of combs. The importance of water for spring brood rearing has been appreciated, but it is still left largely to chance. Protection from wind, whether obtained by utilizing the natural vegetation surrounding the location or by wrapping or packing the hive, is considered beneficial to the colony. To Langstroth's principles may be added exposure to maximum sunlight and freedom from infectious diseases, particularly Nosema.

Langstroth, if living today, would be disappointed in the number of neglected colonies. Yet he would be surprised and equally pleased in the strength of colonies made possible through the use of larger hives, more honey, more pollen or pollen supplements, productive queens, and intelligent management. Such colonies produce correspondingly larger and more certain yields because many of the elements of chance have been eliminated by intensive management.

*Editor's note*—C. L. Farrar, the author of this chapter, has drawn information freely from unpublished reports of the Division of Bee Culture to the Bureau of Entomology and Plant Quarantine, U.S.D.A. In addition, his following publications apply to the subject:

1931. A measure of some factors influencing the development of the honeybee colony. Mass. State Coll. Library, Amherst, Mass. 185 pp. (Typewritten.)

1934. Bees must have pollen. *Gleanings in Bee Culture* **62**(5):276–278.

1936. Influence of pollen reserves on the surviving populations of over-wintered colonies. *Amer. Bee Jour.* **76**(9):452–454.

1942. Nosema disease contributes to winter losses and queen supersedure. *Gleanings in Bee Culture* **70**(11):660–661, 701.

1943. An interpretation of the problems of wintering the honeybee colony. *Gleanings in Bee Culture* **71**(9):513–518.

1944. Nosema disease. *Gleanings in Bee Culture* **72**(1):8–9, 35.

1944. Productive management of honeybee colonies in the northern states. *U.S.D.A. Circ.* **702.** 28 pp.

1945. Food reserves for bees. *Amer. Bee Jour.* **85**(9):313–315, 323.

1947. More honey from bees. *U.S.D.A. Yearbook of Agriculture, 1943–1947, Science in Farming.* pp. 680–685.

1947. Nosema losses in package bees as related to queen supersedure and honey yields. *Jour. Econ. Ent.* **40**(3):333–338.

# XV. *Honey*

BY V. G. MILUM*

IF we consult a modern dictionary, a definition of honey similar to the following is usually found: "Honey is a sweet, viscid fluid elaborated by bees from the nectar collected from flowers, and stored in their nests or hives as food." Inasmuch as nectar is produced by floral nectaries and also by extrafloral nectaries in many plants, the above definition needs to be altered by substituting the words "nectaries of plants" for "flowers." Of course, this definition does not include honeydew which may be the sweet exudates of plants, such as manna, but is chiefly the excretion of certain homopterous insects, such as aphids, leaf hoppers, and scale insects. While feeding upon the sap of plants, these insects excrete from the alimentary canal a sweet liquid material that is sometimes gathered by bees and stored for food, or mixed with true honey in the total or partial absence of a supply of nectar.

True honeys and honeydew, or honeys containing honeydew, are usually distinguished by the terms, "levorotatory honeys" and "dextrorotatory honeys," respectively. Levorotatory honeys are so called because of the rotation to the left of a beam of polarized light passed through them when they are contained in a special optical tube under certain standard conditions. The optical instrument is known as a polariscope, a saccharimeter, or a polarimeter. When honeydew honey is present, the rotation of the beam of light is to the right.

The food and drug administrations of the various states have variable definitions for honey, which for all practical purposes, except for variations in the permitted maximum water content and weight per gallon specifications, are somewhat similar to those of the Service and Regulatory Announcements of the Food and Drug Administration, United States Department of Agriculture:[1] "Honey is the nectar and saccharine exudations of plants, gathered, modified, and stored in the comb by honey bees (*Apis mellifera* and *A. dorsata*); is laevorotatory, contains not more than twenty-five per cent (25%) of water, not more than twenty-five hundredths per cent (0.25%) of ash, and not more than eight per cent (8%) sucrose." Further, the Food and Drug Administration has held that: " 'Honeydew'

---

*Vern G. Milum, Ph. D. Associate professor of entomology (apiculturist), University of Illinois. Formerly instructor in economic entomology, University of Wisconsin. Specialist in studies of honey, moths infecting bee combs, and wintering problems.

[1]Standards of purity for food products. *U.S.D.A. Circ.* 136. p. 11.

honey usually exhibits plus rotation at 20° C., a high plus rotation of the inverted solution at 87° C., an ash content much greater than 0.25 per cent, high nonsugar solids, and is usually characterized by a very dark color and a peculiar molasseslike flavor."

The reader is advised to refer to the minimum requirements for the various grades of honey set up by the United States Department of Agriculture,* as well as to the rules and regulations of his own State regarding the use of established grades which are more strict as to the requirements necessary to meet the limits of particular grades.

Phillips[2] suggests the following definition of honey as useful for all practical purposes: "Honey is an aromatic, viscid sweet material derived from the nectar of plants through the collection of honey bees, modified by them for food into a denser liquid and finally stored by them in their combs, of acid reaction, liquid in its original condition but usually becoming crystalline on standing, consisting chiefly of two simple sugars, dextrose and levulose, with occasionally more complex carbohydrates, with levulose usually predominant, and always containing mineral material, plant coloring materials, several enzymes, and included pollen grains."

## Classifications of Kinds of Honey

1. *Honeys are classified according to the principal plant source* from which the bees gathered the nectar. In many cases, bees in a particular area, because of the abundance of a given honey plant or a few plants of the same type, may work only that source. Due to variations in the sugar concentrations of the nectar, bees may work only one plant source at a time, but in the vast majority of honeys there is apt to be some mixture with nectar from other plants. Usually the predominant nectar source is given as the name of the honey, such as "orange honey," while in other cases a group name, such as "fall flower honey," is used. One particular case always offers a question: when the classification "white clover honey" is used, it may mean the honey of alsike clover, sweet clover, or white Dutch clover.

2. *Honeys are also classified according to types of production and preparation for marketing.* Ordinarily the following are included:

a. *Extracted honey,* sometimes called "strained" honey, is the nectar and saccharine substances of plants gathered, modified, and stored in the comb of the honey bees and separated from the crushed or uncrushed comb by centrifugal force, gravity, straining, or other means. Ex-

*Issued by the Food Distribution Administration, United States Department of Agriculture, effective March 15, 1943, superseding the United States grades recommended by the United States Department of Agriculture in Circular No. 24, issued December, 1927, and revised August, 1933.

[2]Phillips, E. F. 1930. Definitions for honey. *Gleanings in Bee Culture* 58(9):562-566.

tracted honey may be sold in different forms depending on the way it is prepared for market.

(1) *Liquid extracted honey* is that which has usually been heated (not always necessary) in an attempt (not always successful) to prevent granulation.

(2) *Granulated honey,* or *solidified honey,* is extracted honey in the crystallized form, sometimes incorrectly called "sugared honey" or described by suspicious and uninformed customers as "gone to sugar." In granulated honey, the levulose portion remains in a liquid state, surrounding the dextrose crystals.

(3) *Creamed honey* is honey granulated with a soft creamy texture, the granules being very small.* Some honeys naturally granulate this way. Several methods of preparing creamed honey have been developed which vary slightly. By the most approved plan, extracted honey is heated to destroy yeasts and to melt all crystals, then cooled to about 80° F. Slightly more than 5 per cent of ground crystallized honey, or previously processed, finely granulated honey, is added and thoroughly mixed, after which the honey is placed in its ultimate containers and stored at about 57° until fully crystallized. It is then removed to ordinary room temperatures, except for honeys high in levulose content which tend to soften and liquefy at room temperatures. This is the Dyce process and the Cornell Research Foundation, Ithaca, New York, should be consulted regarding patent rights on their process for making creamed honey (Fig. 198).

b. *Comb honey* is honey contained in the cells of the comb in which it is produced.

(1) *Section comb honey* is produced in squares or rectangles, 4¼ by 4¼ by 1⅞ or 4 by 5 by 1⅜ inches, called sections.

(2) *Individual section comb honey* is produced in small sections, usually one-fourth the size of an ordinary section, and is used for individual servings.

(3) *Bulk comb honey* is comb honey produced in shallow extracting-size frames fitted with thin super foundation. When filled, these larger combs may be sold as complete units.

(4) *Cut comb honey* is produced as bulk comb honey, but cut into pieces of various sizes, the edges drained or extracted, and the individual chunks wrapped in cellophane, as a substitute for section comb honey.

(5) *Chunk honey*[3] consists of 40 per cent or more of bulk or section comb honey cut into strips, inserted in containers (usually glass) with the remaining space filled with 60 per cent or less of liquid extracted honey.

*Creamed honey, also marketed under a trade name, "Honey-Creme," differs from *honey cream,* a mixture of honey and cream, which is described in Chapter XVI, "Marketing the Honey Crop."

[3]Amendment 2 to *Revised Maximum Price Regulation 275,* effective November 28, 1945. Office of Price Administration, Washington 25, D.C.

# Composition of United States Floral and Honeydew Honeys*

| | *Floral Honeys* Average | Average | Maximum† | Minimum† | *Honeydew Honeys* Average | Average | Maximum† | Minimum† |
|---|---|---|---|---|---|---|---|---|
| | *92 U.S.* | *106 Calif.* | | | *7 U.S.* | *6 Calif.* | | |
| Water | 17.70 | 16.50 | U26.88 | U12.42 | 16.09 | 15.72 | U17.80 | U13.56 |
| Levulose‡ (fruit sugar) | 40.50 | 40.41 | U48.61 | U24.35 | | 37.5 | C41.9 | C34.2 |
| Dextrose (grape sugar) | 34.02 | 34.54 | U46.40 | U24.73 | | 27.2 | C32.9 | C24.4 |
| Invert Sugars | 74.98 | 74.95 | U83.36 | C60.52 | 66.96 | 64.66 | U71.69 | C59.45 |
| Sucrose (cane sugar) | 1.90 | 2.53 | C11.00 | UC0.00 | 3.01 | 3.45 | C5.74 | U0.61 |
| Dextrins | 1.51 | 0.91 | C11.91 | C0.02 | 9.70 | 9.21 | C14.41 | U6.02 |
| Ash (minerals) | 0.18 | 0.21 | C1.14 | C0.02 | 0.81 | 0.77 | U1.29 | U0.29 |
| Acid | 0.08 | 0.16 | C0.45 | U0.04 | 0.12 | 0.27 | C0.37 | U0.05 |
| Undetermined | 4.9 | 4.72 | C7.51 | U0.04 | 3.43 | 5.91 | C8.18 | U1.57 |

*This table is a compilation of the analyses of 92 United States levorotatory honeys and 7 dextrorotatory (honeydew) honeys from Browne, C. A., 1908, Chemical analysis and composition of American honeys, *U.S.D.A. Bur. Chem. Bull.* **110**: also 106 California honeys and 6 honeydew honeys from Eckert, J. E. and H. W. Allinger, 1939, Physical and chemical properties of California honeys, *Calif. Agr. Exp. Sta. Bull.* **631**.

†The maximum and minimum values represent the highest and lowest values of the combined groups of United States (U) and California (C) floral and honeydew honeys.

‡The honey with a maximum of 46.40 per cent dextrose and a minimum of 24.35 levulose was wild pennyroyal. That with the maximum of 48.61 levulose and a minimum of 24.73 dextrose was the average of two tupelo samples analyzed by Browne.

### Honey Substances of Variable and Minute Amounts

- Pollen grains
  - Partial source of vitamins, minerals, and amino acids
- Beeswax
- Proteins, amino acids, and related compounds
- Substances contributing to color
  - Chlorophyll decomposition products
  - Pigments
    - Carotin (yellow)
    - Xanthophyll (yellow)
    - Of unknown composition (bright yellow and dark green)
  - Anthocyanin (rose red and dark purple)
  - Tannin or tannic acid (dark)
  - Colloidal particles—includes items listed elsewhere
- Substances contributing to aroma and flavor
  - Essential oils
    - Terpenes, aldehydes, methyl anthranilate (an ester)

Volatile and nonvolatile acids including tannic acid
Higher alcohols: such as mannitol and dulcitol
Maltose: sometimes melezitose in honeydew honeys
Enzymes:
- Invertase (converts sucrose to dextrose and levulose)
- Diastase (converts starch to dextrins and maltose)
- Inulase (converts inulin to levulose)
- Catalase (decomposes hydrogen peroxide)

Vitamins: (highly variable amounts)
- Vitamin A (minute and insignificant amounts)
- Vitamin B-complex (several involved in carbohydrate and amino acid metabolism)
  - $B_1$—Thiamine (antineuritic factor, antiberiberi)
  - $B_2$—Riboflavin or vitamin G (growth and metabolism)
  - $B_6$—Pyridoxin (growth and amino acid metabolism)
  - Biotin (nutrition, some relation to dermatitis)
  - Folic acid (growth and nutrition)
  - Nicotinic acid (cure and prevention of pellagra)
  - Pantothenic acid (growth and metabolism)
- Vitamin C—Ascorbic acid (antiscorbutic factor, cure and prevention of scurvy)

## Nectar—Its Composition and Significance

Inasmuch as the nectar of plants is the basic material from which honey is produced by honey bees, we need only to examine the preceding listings of substances in honey to learn the composition of nectar. The only difference between nectar and honey is the variation in the relative amounts of particular substances brought about by the process of ripening. Ripening is defined as the changes produced which result in the reduction of the water content of nectar and the inversion of a part of the sucrose of nectar to levulose and dextrose of honey. Ripening, therefore, changes some of the sugar and, by the reduction of the water content, increases the relative proportion of the other materials with the exception of sucrose.

It appears that the definition of honey ripening may be responsible for a general misconception as to the types of sugars in nectar. Often it is stated that sucrose is the sugar of nectar, but, as early as 1886, the Swiss chemist, Planta,[4] demonstrated that in some plants the invert sugars, levulose and dextrose, actually exceed sucrose in their nectars. This has been further proved by more recent investigators who have shown that in some nectars the levulose may exceed the dextrose, which is in agreement with

---

[4]Planta, A. von. 1886. Ueber die Zusammensetzung einiger Nektar-Arten. *Ztschr. Physiol. Chem.* 10:227-247.

the general composition of most of the resulting honeys where the levulose also exceeds the dextrose. This only could be possible through an excess of levulose in nectar because the inversion of sucrose produces equal molecules of levulose and dextrose.

There are great differences in the rates of nectar secretion and the total amount of nectar secreted by plants. There are also large variations in the relative water and sugar contents of nectar. Vansell[5] reports a sugar content as low as 2.1 per cent (winter Nelis pear) to as high as 65 per cent (alfileria). Many factors are responsible for the cause of these variations: the particular species and even varieties of the same plant, the water content and types of soils on which they are growing, the nature of the flowers—whether closed or open and exposing the nectar to evaporation, the relative humidity as related to general weather conditions as well as variations in atmospheric moisture during various parts of the day, and the amount of air circulation. The particular plants and the soils affect the nectar, as originally secreted, while the nature of the flowers and atmospheric conditions affect the concentration of nectar by influencing evaporation. The total amount of nectar secretion is influenced by other factors, particularly plant vigor, temperature, and sunlight.

The amount of work that bees must do to gather enough nectar to produce a pound of honey is dependent upon the relative proportions of the sugar and moisture content of the nectar. Furthermore, nectar-gathering bees actually show a preference as to which flowers they visit because of the variations in sugar concentration. In some cases, the bees totally ignore flowers having nectar of lower sugar concentrations until other sources of supply are exhausted, or until the sugar concentration has been increased, commonly later in the day, because of the evaporation of moisture from the nectar due to a decreased relative humidity. These conditions indicate some of the problems involved in the cross-pollination of plants and possible variations in the type of honey produced from different species of plants with varying degrees of nectar concentration. For additional information on factors influencing nectar secretion and the behavior of bees in nectar gathering, see Chapter XVIII, "Sources of Nectar and Pollen," and Chapter IV, "Activities of Honey Bees," respectively.

## The Sugars of Honey

An examination of the previous table showing the composition of honeys discloses that honeys consist largely of sugar, the general average being close to 77 per cent total sugars. Further, these sugars are shown to be predominantly levulose and dextrose, with a relatively small amount of sucrose. Maltose in still smaller quantities sometimes is found in cer-

[5]Vansell, Geo. H. 1942. Factors affecting the usefulness of honeybees in pollination. *U.S.D.A. Circ.* 650.

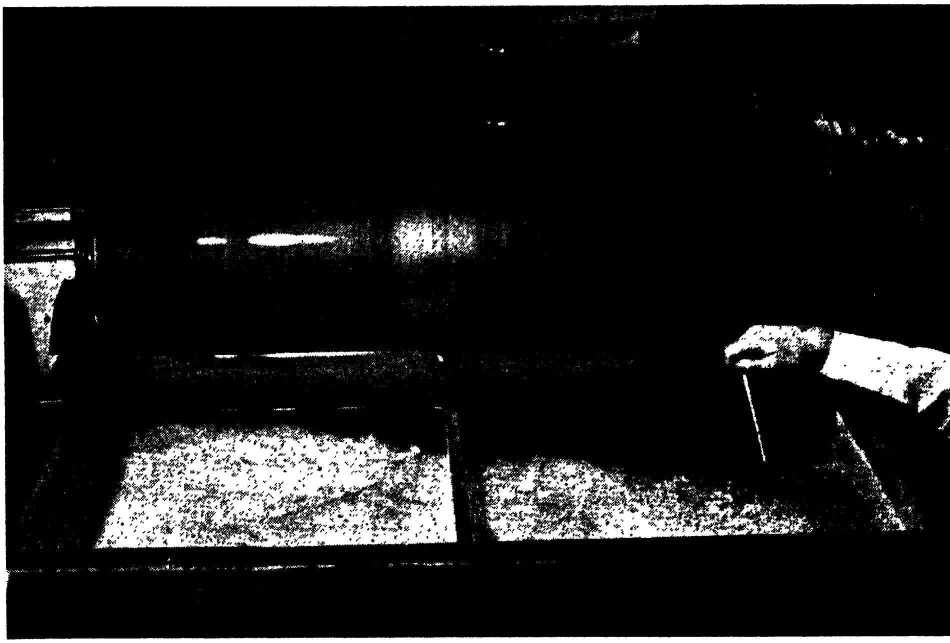


FIGURE 198. Dyce-processing of honey on a commercial scale requires suitable equipment and precise temperature control. Shown here are two large cooling rollers. (*Photo courtesy F. R. Garland*)

tain honeys, while melezitose, common in Persian manna, quite rarely is reported in some honeydew honeys.

Sucrose, or cane sugar, and maltose, or malt sugar—the two disaccharide sugars in the plant kingdom—are so called because they are hydrolyzed, or split, into two simple sugars, or monosaccharides, when treated with acids or enzymes. These units are not further hydrolyzable. Dextrins and maltose are formed when starch is subjected to the action of the enzyme, *diastase*. When one molecule of maltose reacts with acids or enzymes, it is hydrolyzed into two molecules of dextrose. From one molecule of sucrose and one molecule of water reacting with the enzyme, *invertase*, there results one molecule of dextrose and one molecule of levulose. This mixture is called *invert sugar*, and the hydrolysis is called *inversion*. The enzyme serves as a catalyst to aid the chemical reaction. This is the chemical reaction that occurs when bees ripen honey. The water used in the reaction amounts to only one-nineteenth, or 4¼ per cent, of the weight of sucrose when it is changed into dextrose and levulose. This demonstrates that all the excess water of nectar is not used in the process of ripening honey, and that the bees actually must remove a large proportion by evaporation.

Levulose and dextrose are monosaccharides, having in their molecules six atoms each of carbon and oxygen and twelve atoms of hydrogen, $C_6H_{12}O_6$ or $C_6(H_2O)_6$. Because each contains six atoms of carbon, they are

called hexoses; these two are the most common hexoses occurring naturally in plants.

Levulose, also known as fructose and fruit sugar, is usually the most abundant of the sugars in honey. It is quite soluble in water and, when granulation occurs, the levulose is present in a thin film of liquid surrounding the dextrose crystals. Under some circumstances levulose is more completely decomposed than dextrose. This possibly accounts for the formation of dark-colored compounds which cause darkening of honeys and loss of or masking of aroma and flavor when honeys are heated or stored for long periods, particularly at high temperatures. This partial loss of levulose has been advanced as an explanation for the slow granulation of a honey, such as pure sage, which rarely granulates. Because of its sweetness, levulose adds to the general delightful flavor and taste of honey.

Dextrose, or grape sugar, sometimes is called glucose. Dextrose is preferred as glucose is used more commonly for commercial dextrose, or "glucose sirups" such as corn sirup, prepared by the action of hot dilute sulphuric acid, later neutralized with lime. In Nature's laboratory, dextrose easily combines with other sugars and is always a product of the hydrolysis of higher carbohydrates. While the amount of dextrose in honey is approximately twice the water content and is soluble at higher temperatures, at low temperatures a part of the dextrose forms crystals resulting in granulation of honey. The absorption and functions of sugars in the human body are discussed under "Honey as a Human Food" in this chapter.

## Specific Gravity, Weight per Gallon, Water Content, and Hygroscopicity of Honey

The *specific gravity* of a substance is the ratio of its weight to the weight of the same quantity or bulk of water. The weight of a cubic foot of water is 1,000 ounces; hence, a cubic foot of honey weighing 1,412.9 ounces has a specific gravity of 1.4129, which is the standard listed for U.S. Grades A and B.

A honey having a weight of 11 pounds 12 ounces per gallon (231 cubic inches at 68° F.) meets the minimum required weight of U.S. Grade A, or U.S. Fancy, and U.S. Grade B, formerly U.S. No. 1, extracted honey. It further has a Brix hydrometer reading of not less than 79.8° at 68° F. (20° C.), a Baumé hydrometer reading of not less than 42.49° at 60° F. (15.55° C.), a specific gravity of not less than 1.4129 at 68° F., and a refractive index of not less than 1.49 at 68° F. The equivalent of the two hydrometer readings is a moisture content of 18.6 per cent. Honeys with low water content have a greater weight, body, specific gravity, and viscosity.

The specific gravity, water content, and weight per gallon can be determined by means of an instrument known as a hydrometer, a special kind for honey, or by the determination of the refractive index by means of a refractometer. Those who are interested in the determination of the moisture content of honey should consult the tables of Chataway.[6] The method of determination of moisture content by means of a refractometer and the tables have been officially adopted in Canada, and, in 1942, were recommended and adopted for the United States by the Association of Official Agricultural Chemists.[7]

The Relationship Between Various Hydrometer Scales and Refractive Index to Moisture Content and Weight per Gallon of Honey*

| *% Moisture* | *°Bé (Modulus 145) at 60° F.* | *Sp. Gr. (20° C. 20° C.) at 20° C.* | *°Twaddell at 60° F.* | *°Brix at 20° C.* | *Diff. between use of honey hydrometer tables and Brix tables in % $H_2O$* | *Lb. per Imp. Gal. at 20° C. lb.* | *oz.* | *Lb. per U.S. Gal. at 20° C. lb.* | *oz.* | *Ref. Index at 20° C.* | *% Moisture* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13.2 | 45.19 | 1.4510 | 90.2 | 85.45 | 1.35 | 14 | 8 | 12 | 1 | 1.5035 | 13.2 |
| 14.0 | 44.79 | 1.4453 | 89.1 | 84.61 | 1.39 | 14 | 7 | 12 | 0.5 | 1.5015 | 14.0 |
| 15.4 | 44.09 | 1.4352 | 87.1 | 83.13 | 1.47 | 14 | 5.6 | 11 | 15 | 1.4980 | 15.4 |
| 15.8 | 43.89 | 1.4324 | 86.5 | 82.71 | 1.49 | 14 | 5 | 11 | 14.5 | 1.4970 | 15.8 |
| 17.0 | 43.29 | 1.4239 | 84.8 | 81.45 | 1.55 | 14 | 3.8 | 11 | 13.5 | 1.4940 | 17.0 |
| 17.4 | 43.09 | 1.4212 | 84.3 | 81.04 | 1.56 | 14 | 3.2 | 11 | 13 | 1.4930 | 17.4 |
| 18.0 | 42.79 | 1.4171 | 83.4 | 80.42 | 1.58 | 14 | 2.6 | 11 | 12.5 | 1.4915 | 18.0 |
| 18.6 | 42.49 | 1.4129 | 82.6 | 79.80 | 1.60 | 14 | 2 | 11 | 12 | 1.4900 | 18.6 |
| 19.0 | 42.29 | 1.4101 | 82.1 | 79.39 | 1.61 | 14 | 1.4 | 11 | 11.5 | 1.4890 | 19.0 |
| 20.2 | 41.69 | 1.4020 | 80.4 | 78.15 | 1.65 | 14 | 0.2 | 11 | 10.5 | 1.4962 | 20.2 |
| 21.0 | 41.29 | 1.3966 | 79.4 | 77.33 | 1.67 | | | | | 1.4844 | 21.0 |

*Condensed from more extensive tables by H. D. Chataway (see reference No. 6 in this chapter), with additions and slight changes. Printer's errors should be checked if the original tables are consulted. The original tables contain temperature corrections for various scales.

The moisture content of honey is important not only because of its effect upon the weight per gallon, a factor in grading and judging of honey, but also because of its effect upon granulation and fermentation. Variations in water content affect the proportion of ingredients used and also the result obtained when honey is used in recipes for baking and cooking and in mixtures with other products, as when honey is used as a sweetening agent in ice cream. In baked goods, such as breads, cakes, and cookies, the ability of honey to absorb and hold moisture is important. This is also true for certain other materials that have a tendency to dry

[6]Chataway, H. D. 1935. Honey tables, showing the relationship between various hydrometer scales and refractive index to moisture content and weight per gallon of honey. *Canadian Bee Journal* **43**:215.

[7]Walton, George P. 1942. Report on honey and honeydew honey. *Jour. Assn. Off. Agr. Chemists* **25**:681-689. (Ibid. **25**:99. 1942.) (Rev. 1943. *Amer. Bee Jour.* **83**:21.)

out, such as chewing gum and tobacco in various forms. This ability of honey to absorb moisture is known as hygroscopicity and is chiefly due to and in proportion to its levulose content, with some exceptions.

Inasmuch as ripening is, in part, the removal of the variable excess moisture of nectar, how well the bees have performed this duty determines the original moisture content of the resultant honey (see Chapter IV, "Activities of Honey Bees"). The relative humidity of the atmosphere is a definite factor in the ability of the bees to reduce further the water content of the original nectar. In addition, other factors have their effects, including air currents, amount of hive ventilation, proportion of hive and field bees, and storage space in the hive.

After honey is removed from the hives, the most important factor in changing the moisture content of honey is the variation in the relative humidity of the air surrounding the stored honey. Recent investigations by Martin[8] have shown that a liquid honey of 17.4 per cent water content is in equilibrium with water vapor at a relative humidity of 58 per cent, while granulated honey tends to attain equilibrium at a slightly higher relative humidity. Practically speaking then, a honey of higher water content would lose water at 58 per cent or lower relative humidity, and a honey of water content lower than 17.4 per cent would absorb water at 58 per cent or greater relative humidity. From this it is concluded that a relative humidity of not over 60 per cent gives the best storage conditions.

Thus it is apparent that the water content of a thin honey can be reduced by exposing it in a thin layer in a dry atmosphere or, perhaps more efficiently, by passing currents of warm, dry air over its exposed surface. Well-equipped bottling plants have vacuum equipment for removing excessive moisture from honey, but there is danger of reducing the aroma and flavor.

## Body and Viscosity of Honey

Viscosity is a term used to describe the thickness and rate of flow of a liquid. A thick, slow-flowing or heavy-bodied honey has a high viscosity, while a thin, free-flowing honey with a light body is said to have a low viscosity. In general, liquid honeys high in water content have a poor body and a low viscosity, while those with a low water content have a good body and a high viscosity. The viscosity of a honey can be increased by cooling, which will not change the water content or the relative body. On the other hand, heating a honey decreases the viscosity but does not change the body unless some moisture is driven off. Reversing this process, a honey exposed to a moist atmosphere may absorb some moisture due to its hygroscopic nature which would thus result in a poorer body, as well as a lower viscosity, and the speed of flow would be increased.

---

[8]Martin, E. C. 1939. The hygroscopic properties of honey. *Jour. Econ. Ent.* 32(5):660-663.

The body of honey has a practical significance; good-bodied honeys are low in water content, hence are preferred by buyers and thus should (and usually do) command a better price. That body is an important characteristic of honey is indicated by its allotment of a large share of the total points in the score card for extracted honey in exhibits at fairs. A true test of the body of a honey can be obtained by determination of its specific gravity and moisture content by means of a hydrometer.

One may gain some indication of the comparative body of two honeys by inverting the closed jars and noting the speed of the rising air bubbles. However, the temperature of the honeys, the size of the containers, and the relative size of the bubbles directly influence the rate of rise. A honey judge should, therefore, assemble the competing honeys at a common point long enough for them to acquire a common temperature. Rather than note the rising air bubbles, a better comparative test may be made by stirring the surfaces of the honeys with uniform glass or wooden rods, or even observing the speed of flow as they drip from the rods.

As already indicated, water content and temperature materially affect viscosity, but other factors include dextrins and the relative proportions of levulose and dextrose. Because heating decreases viscosity, which means increasing the rate of flow of honey, blending (mixing) and straining of honey is thereby greatly facilitated. Likewise, the lower viscosity of honey during warm weather is a distinct aid in more rapid and complete extraction of honey from the combs.

## Thixotropic Honeys

Thixotropy is defined as the property or phenomenon exhibited by some gels of becoming fluid when shaken, the change being reversible upon standing. The heather honey of Europe is the classic example of a thixotropic honey which usually has such a high viscosity that it must be shaken or agitated in some manner before it can be extracted. This behavior of heather honey has been attributed to the presence of some colloidal substance, the removal of which causes the jellylike condition to disappear entirely. It is claimed by Beveridge[9] that pure heather honey never granulates or loses its jelliness, but complete granulation results in time if 10 per cent or more of other nectar is present, which is invariably true if produced below elevations of 1,000 feet. A method of "needling" or loosening heather honey before extraction to induce a change from the jellylike substance to the fluid state has been described. Recent investigations by Munro[10, 11] indicate that buckwheat honey shows a slight trace, and sweet clover a mere trace, of thixotropic tendencies, but these are not sufficient to affect extracting.

[9]Beveridge, J. 1935. National show, 1935. *Bee World* **16**:140-141.

[10]Munro, J. A. 1943. The viscosity and thixotropy of honey. *Jour. Econ. Ent.* **36**:769-777. (7 refs.)

[11]———. 1944. Some physical properties which affect the handling of honey. *Gleanings in Bee Culture* **72**:41-43.

## Mineral Constituents of Honey

Although the mineral or ash content of honey does not seem to be very high, honey added to the diet in place of sugar does increase the total mineral content of the food intake and thereby adds to the other values of honey. Minerals in variable amounts are absolutely essential for growth and for maintenance of health. For instance, the function of iron is in connection with the hemoglobin which has the power of holding iron in such a way that, when the blood stream passes through the lungs, oxygen is absorbed from the air and carried to the muscles where it is needed and consumed (see "Honey in Infant and Child Feeding" in this chapter). Iron apparently is assisted by copper as a catalyst in restoring the hemoglobin content of the blood in patients afflicted with anemia. Iron, as well as phosphorus, is a constituent of chromatin and is concerned with vital activities of cells. Magnesium is deemed a valuable component in nutrition, although there are some differences of opinion as to its specific use. It is found chiefly in bones but also in muscles and blood. Chlorophyll, the green pigment of plants, is a complex, organic magnesium compound of unknown structure.

Mineral Constituents of Honey (Parts per Million)*
(Rearranged from Schuette et al.†)

| *Element* | *Number of Samples*‡ | *Light Honeys* | | | *Dark Honeys* | | |
|---|---|---|---|---|---|---|---|
| | | *Average* | *Minimum* | *Maximum* | *Average* | *Minimum* | *Maximum* |
| Potassium | 13, 18 | 205 | 100 | 588 | 1676 | 115 | 4733 |
| Chlorine | 10, 13 | 52 | 23 | 75 | 113 | 48 | 201 |
| Sulfur | 10, 13 | 58 | 36 | 108 | 100 | 56 | 126 |
| Calcium | 14, 21 | 49 | 23 | 68 | 51 | 5 | 266 |
| Sodium | 13, 18 | 18 | 6 | 35 | 76 | 9 | 400 |
| Phosphorus | 14, 21 | 35 | 23 | 50 | 47 | 27 | 58 |
| Magnesium | 14, 21 | 19 | 11 | 56 | 35 | 7 | 126 |
| Silica ($SiO_2$) | 14, 21 | 22 | 14 | 36 | 36 | 13 | 72 |
| Silicon (Si) | 10, 10 | 8.9 | 7.2 | 11.7 | 14 | 5.4 | 28.3 |
| Iron | 10, 10 | 2.4 | 1.2 | 4.8 | 9.4 | 0.7 | 33.5 |
| Manganese | 10, 10 | 0.30 | 0.17 | 0.44 | 4.09 | 0.52 | 9.53 |
| Copper | 10, 10 | 0.29 | 0.14 | 0.70 | 0.56 | 0.35 | 1.04 |

*The parts per million equal the milligrams per kilogram, or divided by 10,000 equal the actual per cent of the total honey composition.

†Schuette, H. A. and D. J. Huenink. 1937. Mineral constituents of honey. II. Phosphorus, calcium, and magnesium. *Food Research* 2:529-538.

†Schuette, H. A. and R. E. Triller. 1938. Mineral constituents of honey. III. Sulfur and chlorine. *Food Research* 3:543-547.

†Schuette, H. A. and W. W. Woessner. 1939. Mineral constituents of honey. IV. Sodium and potassium. *Food Research* 4:349-353.

†Schuette, H. A. and K. Remy. 1932. Degree of pigmentation and its probable relationship to the mineral content of honey. *Jour. Amer. Chem. Soc.* 54:2909-2913.

‡The first figure refers to the number of samples of light honeys, while the second figure refers to the number of samples of dark honeys.

Sodium salts are abundant in the blood and other body fluids, and in lower concentration in tissues and organs. Greater than any other mineral is the amount of calcium in the body, particularly in bones, teeth, and blood. Sulfur and manganese are nutritionally essential; lack of the latter induces serious disorders. Chlorine, as chlorides, is found in all body fluids and muscle cells, and large amounts are found in red blood cells.

An examination of the table showing the mineral constituents of a large number of honeys ranging from water white to dark shows the relative amounts of different minerals in honeys. Considering the average of the two groups, the greater amounts of every element occur in the darker honeys as a group. However, if the minimum amounts are examined, it will be noted that some of the individual darker honeys contain the least amounts of calcium, silica, magnesium, and iron.

While a study of this table seems to indicate a better nutritional value for the darker honeys from the standpoint of the mineral content, one should remember that the dark color of a particular sample of honey may not be due to its original content, but may be the result of darkening in processing and storage. Examination of the complete information given in the original report[12] on 106 California honeys indicates lack of a close correlation between total mineral content and degree of color. Numerous combinations of pairs of samples could be selected in which the lighter honey was reported to have a greater mineral content than the selected darker honey.

At least four separate investigations have demonstrated that honey yields a decidedly alkaline ash, with dark honeys most alkaline and light honeys, such as clover honey, least alkaline. Thus the potential alkalinity closely parallels the ash content, from the light to the dark honeys.

## Dextrins in Honey

Dextrins are defined as the first series of products resulting from the breaking down of starches. The crust of bread contains considerable dextrin, as heat transforms starch into dextrin. The practical significance of dextrins in honey is that they have a definite influence toward increasing its viscosity and body. Because of their gummy nature, honeys high in dextrins tend to have a sticky characteristic, particularly honeydew honeys. The gummy adhesive material on the back of postage stamps and labels is dextrin.

In the previous table, "Composition of United States Floral and Honeydew Honeys," the dextrin content of honeydew honeys shows a variation from 6.02 to 14.41 per cent, and from 0.02 to 11.91 per cent for floral honeys. These extremes in floral honeys are for the 106 Cali-

[12]Eckert, J. E. and H. W. Allinger. 1939. Physical and chemical properties of California honeys. *Calif. Agr. Exp. Sta. Bull.* **631.**

fornia honeys in which the average dextrin content was three-fifths that of the 92 U. S. honeys. If two of the California honeys, western hyssop and fleabane, having a positive polarization at 20° C. are disregarded, then the remaining 104 California honeys show a high limit of 3.31 per cent dextrin content, this being found for a mixture of star thistle and California buckeye honeys. It is possible that the first two samples of honey might have been contaminated with some honeydew honey. The complete report on the California honeys indicates that the dextrin content varies widely within honeys from the same designated floral source, but this may have been due to contamination with honey from other sources. The report also indicates that the percentage of undetermined materials, in general, were higher in honeys having a higher dextrin content.

Because bees are unable to digest dextrins, their presence in honeys, especially honeydew honeys, simply adds to the total of indigestible matter and water that must be stored in the body of the bee until opportunity for elimination in flight occurs. In winter, honeys high in dextrins, along with other factors, tend to further the development of dysentery.

## Proteins, Amino Acids, and Related Compounds

As proteins are compounds of great importance in plants, it is only natural that some of them are to be found in nectar and pollen, particularly those that are soluble in water and those that owe their presence to the pollen content of honey. Proteins are of complex structure being made up of simpler nitrogen compounds, known as amino acids, joined together to form large, frequently complex molecules. They consist principally of carbon, hydrogen, nitrogen, oxygen, and sometimes sulfur. Proteins exist in honey as fine colloidal particles or in true solutions as the decomposition products, the amino acids.

Amino acids are soluble in water; some are only weakly acid, others are alkaline. They are derived from proteins by hydrolysis with either acid or base, as well as by enzymatic action. All digested proteins enter the blood stream as amino acids to be carried to and used in the building up of body tissues.

Determinations of proteins in honey by Browne[13] have shown a variation of 0.106 to 0.563 per cent in seven honeys. For 18 Texas honeys an average protein content of 0.36 per cent was found by Fraps,[14] while another investigator reported a variation from 0.03 to 2.67 per cent for European honeys. The pollen content of the latter was apparently quite high. The amount of proteins in honey is not important nutritionally

[13]Browne, C. A. 1908. Chemical analysis and composition of American honeys. *U.S. Bur. Chem. Bull.* 110.

[14]Fraps, G. S. 1921. The chemical composition of Texas honey and pecans. *Texas Agr. Exp. Sta. Bull.* 272.

as a pound of honey per day would supply only a small part of the daily human requirement.

Proteins in general are known to be extremely sensitive to chemical and physical agents, such as acids, alkalies, alcohol, heat, mechanical shaking, and ultraviolet light. While a relationship between color, or degree of pigmentation, and the amount of nitrogenous matter found in honey has been reported by Schuette,[15] what is more important is that the proteins in honey, at least the amino acids, appear to have a pronounced effect in the development of color (discoloration), and in the loss of or masking of delicate flavor and aroma when honey is heated or when it is stored at high temperatures. (See "Honey Discoloration and Loss of Flavor and Aroma" in this chapter.)

## Acids in Honey

Investigations by Nelson and Mottern[16] indicate that the organic acids of honey may be divided into two classes: volatile and nonvolatile. They list acetic and formic as the volatile acids, the latter in small amounts. The nonvolatile acids are largely malic, citric, and in some samples succinic. It is not surprising that malic and citric are found in honey because they are widely distributed in plants and fruits. Occasionally listed in additional reports are other organic acids, including lactic, tartaric, and oxalic. In some honeys, such as buckwheat, tannic acid in addition to giving an astringent taste probably is responsible for dark colors, because it forms a bluish-black compound in combination with ferric (iron) salts. The inorganic phosphoric acid is listed by some authors.

Bacterial spoilage and fermentation of honey is impossible because bacterial growth is prevented by an acidity as high as that of honey. But honey spoilage by the sugar tolerant yeasts causing fermentation is apparently unaffected, for these yeasts grow very well in a medium having an acidity comparable to that of honey.

## Vitamins in Honey*

The discovery of vitamins and their important role in the promotion of health and prevention of disease has been listed as one of the greatest scientific achievements of modern times. While much has been learned about them, there still remains much to be added to the story of vitamins in different foods, and this is particularly true of honey. When a list of references is consulted, it is found that the earliest that the vitamin content of honey was mentioned and investigated was 1918. No doubt the

[15]Schuette, H. A. 1933. What value color in honey. *Amer. Bee Jour.* 73:308-309.

[16]Nelson, E. K. and H. H. Mottern. 1931. Some organic acids in honey. *Ind. and Engin. Chem.* 23(3):335-336.

*For a list of vitamins in honey see the previous listing of "Honey Substances of Variable and Minute Amounts."

methods employed in earlier investigations, which methods have been improved in recent years, explain the various conflicting reports and contentions. The favorable results secured in experiments in which honey was used in infant feeding should have aroused suspicion of the presence of vitamins and other qualities, and no doubt was convincing to some investigators.

With the development of modern methods for the detection of vitamins by biological assay, definite proof of the existence of certain vitamins in honey has been given. In the period, 1935 to 1940, several European investigators seem to have established by biological-assay methods the presence of vitamin C (ascorbic acid) in a large number of honeys, but the amounts showed great variation. One reported that the vitamin C content, although quite stable, does decrease with age. In 1935, Markuze[17] reported having found vitamin $B_2$ (riboflavin) in two samples of honey.

Experiments at the University of Minnesota,[18] reported in 1942, and at the University of Wisconsin,[19] in 1943, have shown the presence of vitamin C and various components of the vitamin B-complex, some in amounts comparable to those in certain other foods. Examinations at Wisconsin of new and old honeys indicated that new honeys contained more pantothenic acid. In the Minnesota report, a comparison of five components of the vitamin B-complex in a sample of unclarified (unfiltered) honey with the same honey after clarification in the laboratory showed losses ranging from 29.6 to 47.1 per cent. Later Haydak and his associates reported comparative losses varying from 8 to 45.0 per cent in samples of unclarified honeys received from two commercial packers. These losses are attributed to the removal of pollen and the absorption of some of the vitamins in the honey by the diatomaceous earth used in filtering.

It appears significant in the Wisconsin report that the analyses of pollen and royal jelly for the components of the vitamin B-complex show a variation from 49 to 378 times as much in pollen as in honey, while for royal jelly the amounts of the various vitamin B components varied as much as 101 to 6,212 times as much as in honey.

While working on the role of honey in the cure of nutritional anemia in rats, University of Minnesota investigators[20] were impressed by the fact that the coagulability of blood in the rats receiving a honey supplement was so high that it was sometimes difficult to draw samples for the hemoglobin determinations. This observation prompted another investi-

---

[17]Markuze, Z. 1935. The vitamin content of honey. *Arch. Chem. Farm.* **2**:175-182.

[18]Haydak, M. H., L. S. Palmer, M. C. Tanquary, and A. E. Vivino. 1942. Vitamin content of honey. *Jour. Nutrition* **23**:581-588.

[19]Kitzes, George, H. A. Schuette, and C. A. Elvehjem. 1943. The B vitamins in honey. *Jour. Nutrition* **26**:241-250.

[20]Haydak, M. H., L. S. Palmer, and M. C. Tanquary. 1942. The role of honey in the prevention and cure of nutritional anemia in rats. *Jour. Pediatrics* **26**(6):763-768.

gation[21] in which buckwheat, alfalfa, and mixed honeys, when fed incorporated in basal ration to vitamin K depleted chicks, were found to possess a definite antihemorrhagic activity, which was greatly lowered when honey was administered directly to the vitamin K depleted chicks.

From the information available up to 1949, it appears that the vitamin content of honey, although definitely proved, is quite variable, depending upon the plant source of the nectar, the age of the honey, the variable amount of pollen present, and the processing and storage treatment given the honey, with the latter factor still needing further investigation. Inasmuch as honey is not rich in vitamins, it cannot be used as an abundant source, but it does help to supplement the supply from other foods which also are needed for the metabolism of the sugar portions of honey when it is ingested.

## Enzymes in Honey

Enzymes are catalytic bodies formed by living tissues which by their specific action aid or quicken the reaction, chiefly chemical, between two other substances, either to build up more complex substances or to break them down into more simple substances, without themselves becoming a part of the reaction. Every enzyme performs in a different reaction. They act at low temperatures and are somewhat unstable, being sensitive to moisture and temperature conditions. Thus the enzymes of honey are affected somewhat by methods of preparation for marketing, particularly as to the amount of heating and the storage temperature.

While the functions of enzymes are particularly important in the plant processes having to do with the secretion of nectar, only *invertase* which converts sucrose to dextrose and levulose is thereafter of significance. As nectar may contain large amounts of sucrose, invertase has an important role in the ripening of honey by the bees. Honey as a source of this enzyme has some value in digestion of sugar, particularly by infants.

There has been much discussion in the literature regarding the enzyme, *diastase,* or *amylase,* which changes starches in plants to maltose sugar and dextrin. Its presence in honey is variable and small amounts are not of great importance as an aid in human digestion, because saliva contains in abundance another enzyme, *ptyalin,* which in the human body brings about the same changes produced by diastase in plants. In addition, pancreatic juice contains still another enzyme, *amylopsin,* which digests to glucose any starch not affected by the saliva. The general trend of investigations seems to indicate that there is a great variation in the diastase content of the original honeys, darker honeys having greater amounts of diastase. Heating does not seriously reduce the diastase content if excessive temperatures are not used.

[21]Vivino, A. E., M. H. Haydak, L. S. Palmer, and M. C. Tanquary. 1943. Antihemorrhagic vitamin effect of honey. *Proc. Soc. Exp. Biol. and Med.* **53**:9-11.

## Pollens in Honey

The pollen content of honey varies considerably with the source of nectar, the type of comb in which honey is stored, and the methods of straining or filtering in processing honey for market. Nectar from certain honey plants contains little pollen while with others larger amounts of pollen are incorporated in the nectar. This undoubtedly is closely related to the size of the flower and the proximity and arrangement of the nectaries and the anthers which shed the pollen. If surplus storage combs having cells of pollen are used, there may be more pollen in the honey. A certain amount of pollen rises to the surface in settling tanks, depending somewhat upon the viscosity of the honey. The method of straining, particularly as to the size of the filter pore and whether pressure or suction is used, influences the amount of pollen remaining in the honey.

While microscopical examination of a honey for the presence of pollen grains may give some clues to its identity or indicate the possibility of mixing of different honeys, the amount of the pollen grains of different plant species in a given sample of honey cannot be used to determine the proportions of nectar from the different species. In fact, certain wind-blown pollen, such as that of corn and grasses, may be found in the honey of certain plants which contain less of their own respective pollens.

## Colloids in Honey

Colloids consist of large molecules (i.e. proteins) or aggregates of smaller molecules (as colloidal gold) which are dispersed in a liquid medium and show little or no tendency to settle. Thus colloids represent a state of subdivision which is intermediate between materials in solution and those in suspension in which the particle size is not large enough to settle readily.

According to Lothrop and Paine,[22] the colloids of honey are gummy, noncrystalline substances consisting largely of nitrogenous compounds (proteins), highly emulsified wax particles, pentosans, and inorganic constituents. These authors with Gertler[23] report that some dark honeys, such as buckwheat, contain as much as 0.8 per cent of colloidal materials, while light honeys usually contain around 0.2 per cent, but may be as low as 0.07 per cent (mangrove). In other publications, Lothrop and his co-workers discussed the effect of colloids on various properties of honey which are considered elsewhere in this chapter.

[22]Lothrop, R. E. and H. S. Paine. 1931. The colloidal constituents of honey and their influence on color and clarity. *Amer. Bee Jour.* **71**:280-281, 291.

[23]Paine, H. S., S. I. Gertler, and R. E. Lothrop. 1934. Colloidal constituents of honey. Influence on properties and commercial value. *Ind. and Engin. Chem.* **26**:73-81. (Rev. *Bee World* **16**:22.)

## Colors of Honey

According to U. S. Grades, the colors of honey vary from water white or practically colorless honeys, such as clover, basswood, and fireweed, to the extremely dark honeys, such as buckwheat and European heather honeys. In between these extremes, the remaining accepted standard colors are extra white, white, extra light amber, light amber, and amber. However, some honeys may actually appear to be reddish, purplish, greenish, bluish, or golden in color.

The chief significance of honey color is its practical application as a clue to other characteristics, such as flavor, its probable mineral content, and the treatment to which it has been subjected during extracting, processing, and storage. Whenever honey is darkened by any treatment applied to it, there is also an impairment of flavor toward the stronger side with a loss of some of the original aroma. Color and flavor in honey seem to be rather closely associated for, in general, light-colored honeys are mild in flavor and dark-colored honeys are strong in flavor.

The color and flavor of honey from a particular kind of plant are due to the variations in the amounts and the chemical nature of the constituents of the original nectar. The greatest variations apparently are related to differences in types of soils and to the rapidity of the honeyflow or volume of nectar secretion. In general, a particular type of honey from a certain species of plant is lighter in color and milder in flavor when the honeyflow or nectar secretion is more abundant, and darker in color and stronger in flavor with a less abundant nectar secretion.

It is entirely possible that the amount of sunlight has a direct effect upon the color of nectar. While heat as a result of sunlight would tend to darken honey, light alone has been shown[24, 25] to reduce the amount of discoloration in samples of honey in storage. In partial substantiation of this is the fact that honey from the same species of plant at high altitudes with intense sunlight is lighter in color than that produced at low altitudes. However, differences in soils, rapidity of honeyflow, and variations in amounts of nectar from other plants may be involved.

While it has been indicated that there appears to be some correlation between the mineral content of honey and its pigmentation (that is, greater amounts of most of the minerals being in the darker colored honeys as originally gathered), the extent to which mineral elements actually contribute to honey color has not been demonstrated. The fact that most of the minerals, as well as sugars, give a water-white solution suggests that other materials are responsible for honey color.

---

[24]Milum, V. G. 1939. Honey discoloration and loss of delicate flavor in processing and storage. *Amer. Bee Jour.* 79:390-392, 416. (13 refs.) *Also see* pp. 445-447. (13 refs.)

[25]———. 1948. Some factors affecting the color of honey. *Jour. Econ. Ent.* 41(3):495-505. (19 refs.)

The constituents of honey which are known to contribute to the original color of honey are various plant pigments, tannin bodies, chlorophyll derivatives or decomposition products, and colloidal particles. A sugar derivative, anthocyanin, is reported by Phillips[26] as being responsible for the rose-red color of white clover honey at high altitudes and the dark purple of willow herb honey of Alaska.

Among the plant pigments found in honey is carotin which is a common source of yellow color in many plants. It unites with oxygen to form xanthophyll, another yellow plant dye found in honey. Bright-yellow and dark-green plant pigments found in honeys are of large molecular structure but of unknown composition. Tannin bodies in honey give it a dark color, a common example being buckwheat honey.

Listed above as affecting the color of honeys were the derivatives or decomposition products of chlorophyll which is the green coloring material of plants. With the aid of the energy of the sun, chlorophyll has the ability to combine carbon dioxide and water to form sugars which have high food and energy values. During this process, chlorophyll is broken down and again built up with the aid of an enzyme, this accounting for the possibility of some of these simpler products in solution getting into the plant sap and later being secreted with the nectar to affect its color.

Lothrop and Paine[27] report that removal of the colloidal materials from honey by ultrafiltration tends to improve the color and clarity of honey. This would seem to indicate that some of the plant pigments or chlorophyll bodies might be present in colloidal suspension.

A discussion of the color of honeys would not be complete without calling attention to the fact that the apparent color of honeys is influenced by the color of the glass container, the quantity and color of light behind the glass container, and the mass or volume of honey through which the light passes. Honey in a tall, slender jar thus will appear to be lighter in color than the same amount of honey in a short, squatty jar. The taller jar perhaps has a slight advantage in honey exhibits, but the short jar is more desirable because of its larger opening, compactness, and lessened tendency of tipping. This variation in apparent color presents a problem to the packer who bottles more than one size. It is reported that some use a darker blend for smaller bottles so that two or more sizes will have the same apparent color when displayed together on the retail counter.

## Aroma and Flavor of Honey

The delightful aroma of honey is due to essencelike essential oils which give it a characteristic odor or bouquet. Some of the essential oils are

[26]Phillips, E. F. 1929. Sources of honey colors. *Gleanings in Bee Culture* **57**:362-365. (This reference is one of a series of 22 highly informative articles on honey by Dr. E. F. Phillips, published in *Gleanings in Bee Culture*, volumes **56** to **58**, 1928 to 1930.)

[27]Lothrop, R. E. and H. S. Paine. 1933. The turbidity of honey in relation to colloidal constituents present. *Amer. Bee Jour.* **73**:53, 57.

terpenes while others are aromatic aldehydes. The distinctive and pleasant odor of orange honey is attributed to an ester, methyl anthranilate,[28] which has not been reported in any other honey. These substances are usually quite volatile and are driven out easily by heating which partially complicates the problem of care and preparation of honey for marketing. It thus follows that flavor and aroma, in a sense, give an indication of the treatment that may have been given to honey if the usual flavor of honey from the original nectar source is known. Likewise, because of the relation between color and flavor of honeys, an accurate designation by the honey producer of the color grade from a particular flower source gives an indication to the experienced buyer of the quality of the honey involved.

There is little information in the literature as to the effect of acids on the aroma and flavor of honey. The volatile acids, acetic and formic, probably affect the aroma to a slight degree, while both these and the nonvolatile acids—malic, citric, and succinic—have a small effect on odor and flavor, they themselves being reduced in intensity by the presence of the minerals. In some honeys, such as buckwheat, an astringent taste is due to a coloring matter, tannin or tannic acid.

From the standpoint of human consumption, the real significance of aroma and flavor is the effect upon the palatability of foods, with the resultant increase in the enjoyment of eating. There are those who claim that this satisfaction stimulates greater secretion of digestive juices, increasing the efficiency of digestive processes.

The flavor and odor of honeys seem to be somewhat concentrated in honeys fresh from the comb or from the extractor. Also, the apparent odor and flavor is affected by the physical condition at the time it is tasted. Warm honeys seem to have somewhat more volatile odors but, of course, too much heating may drive off a large amount of the natural bouquet. In eating granulated honey, it takes longer to get the true taste, for the crystals have to be dissolved to get the full effect, the larger the crystals the greater being the delay.

While most of the odors and flavors are delightful, occasionally honeys are actually unpalatable. With some honeys, bitter tastes that are present when ripening has been completed may later disappear. One sample of golden fall honey (source not definitely determined) had a bitter gall-like taste when removed from the hive but the unpleasant taste, even in the uncapped combs, had completely disappeared within a year. With other honeys, the odor and flavor may not at first be pleasing to an individual accustomed to another honey, perhaps not as dark colored and strong flavored, but a liking for the distinct-flavored honeys actually may be developed. It is often said that one prefers the honeys of his home locality, that is, the type or flavor of honeys that one has been accustomed to eating.

[28]Nelson, E. K. 1930. The flavor of orange honey. *Ind. and Engin. Chem.* **22**:448.

## Sweetness of Honey

There seems to be no definite agreement on the comparative sweetness of honey. The relative sweetness of the principal sugars found in honey has been indicated as follows: sucrose (cane sugar), 100; levulose (fructose), 173; dextrose (glucose), 74; invert sugar, 123; and maltose (malt sugar), 32. One can find figures in the literature varying from 47 up to 123 or more for honey as compared to 100 as a standard for cane sugar. The lower figures are expressed by those using honey in the manufacture of dairy products, while the higher figures are expressed by chemists. As a sweetening agent in ice cream, honey is considered by Tracy[29] to be 75 per cent as sweet as sucrose, 1.3 pounds being required to equal the sweetness of a pound of sucrose.

The presence of essential oils and other materials which give flavor to honey apparently accentuates its sweetness when taken undiluted. People who use honey to sweeten beverages know that it requires more honey than sugar to attain the degree of sweetness to which they are accustomed, although they may learn to use less because of the flavor of the honey.

## Changes Occurring in Honey After It Is Produced by Bees

For the vast majority of honeys, the product as produced by the bees is one of more or less delectable quality, but unfortunately certain physical and chemical changes may occur which usually have a tendency to impair its quality. The chief changes are due to moisture absorption, granulation, fermentation, discoloration or darkening, and loss of or masking of the originally delicate flavor and aroma of the honey. These changes are more or less interrelated.

Moisture absorption may affect granulation and either or both may influence fermentation. The latter may in turn be prevented by elimination of granulation by storage or heating, all of which may have a direct effect upon color, flavor, and aroma of honey. Conditions which may prevent one or more of these physical and chemical changes from having a deteriorating effect upon one quality of honey may not be sufficient to eliminate the other causes of losses. Because of the complexity and interrelation of these various factors, it is probably best to consider each separately. For additional information concerning the handling and extracting of honey, see Chapter X, "Management for Extracted Honey Production," and Chapter XI, "Extracting the Honey Crop."

[29] Tracy, P. H., H. A. Ruehe, and F. P. Sanmann. 1930. Use of honey in ice-cream manufacture. *Ill. Agr. Exp. Sta. Bull.* **345**.

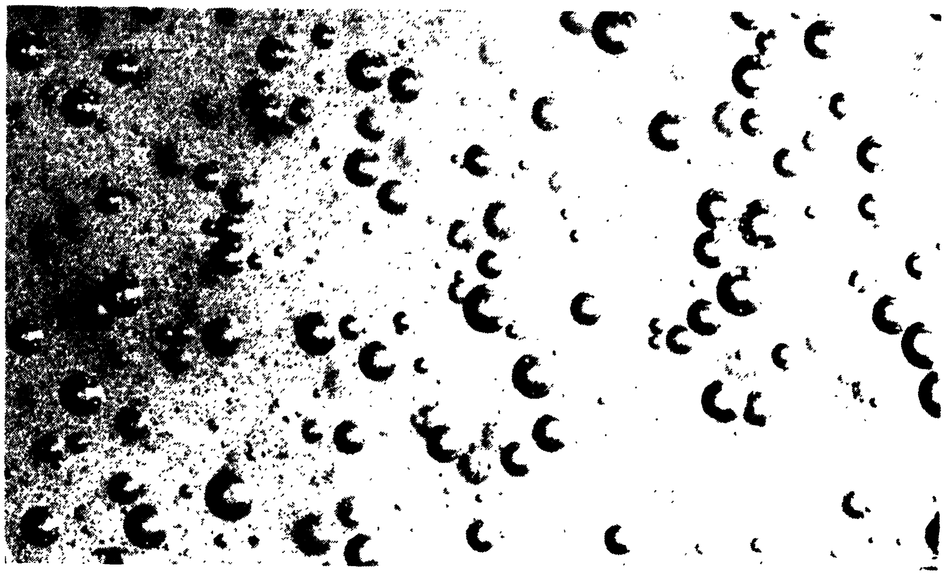


FIGURE 199. Enlarged photograph of tiny air bubbles, incorporated in the honey by faulty handling, and reducing the clarity of the liquid honey. (*Photo by Wm. M. Harlow*)

## Turbidity and Clarity of Honey

The clearness of honey is affected chiefly by the amount of incorporated air, its water content, and its colloidal content, the effect of the latter having been shown to be influenced by the acidity of the honey (see reference No. 22 in this chapter).

Air becomes incorporated in honey when it is thrown out in fine streams against the extractor walls, by improper pumping, by pipe lines that are too small, and by allowing honey to fall from a distance into liquid honey when straining and when filling containers. The air bubbles tend to rise to the surface of warm honey, but many minute air bubbles remain in the honey reducing its clarity (Fig. 199).

Granulation also affects the clarity of honey. This begins with the first formation of dextrose crystals and increases as granulation continues. After granulation, the clarity of honey is sometimes affected by an apparent foaming when it is heated. This is the result of fermentation following granulation with the formation of carbon dioxide gas, the finely divided bubbles giving the honey a turbid appearance. By careful heating, this gas may be driven off and the clarity partially restored.

## Effects of Straining, Filtering, and Clarifying

Any actual difference between filtering and straining of various kinds is merely a matter of degree. With settling or gravity straining, where the

honey is allowed to stand in tanks for a time before processing, a certain amount of pollen, wax particles, and other introduced substances rises to the top where they may be skimmed off or removed by rolling them up in a damp cloth patted down over the thin layer of scum. When honey is heated, still further amounts rise to the surface. In straining after heating, the amount of materials removed depends upon the actual size of pores in the filtering cloth and whether pressure or suction is used, the latter tending to pull more of the small particles through the cloth.

Filtering is a term now commonly used for somewhat more modern methods of clarification by use of diatomaceous earth, or other filter medium, as an aid to prevent the clogging of the filter pores and to remove colloidal particles. Besides a claimed increased speed of operation, such filtering is said to make the honey more clear, less liable to foam and form scum layers, less likely to caramelize when heated, and less apt to granulate. Not all are distinct advantages for filtering over straining because, if honey is heated and strained properly, some of the same advantages are obtained. As far as the tendency to granulate is concerned proper heating is the really critical factor. While honey clarified by filtering may have more appeal to the customer's eye and definite advantages when used in certain products, there still seems to be some question as to the advisability of extreme clarification. Not only has it been shown that samples of honey had a reduced vitamin content after filtering (see "Vitamins in Honey"), but it has been suggested that colloids have an electrical charge, attracting and holding portions of minerals which together would be removed. Although present in small amounts, minerals in honey have distinct and definite values in human nutrition.

## Granulation of Honey

Granulation of honey is that phenomenon in which the dextrose sugar content is unable to stay in solution at a given temperature (Fig. 200). In other words, this concentrated solution of sugar in water becomes supersaturated with dextrose, some of which forms crystals, surrounded by the remaining liquid portion. Under favorable conditions, so many of the dextrose crystals are formed that the whole volume of the honey assumes a creamy consistency at first, and later a somewhat solid mass although the other sugars are in a liquid film about the individual dextrose crystals. This action sometimes is called "sugaring" or crystallization; a frequent expression is that the honey has "gone to sugar."

When honeys granulate naturally and quickly with the formation of very fine crystals, a creamy consistency results and the product is often called "creamed honey." Creamed honey may result from natural crystallization or as the result of seeding extracted honey with very fine crystals, followed by stirring and storage at temperatures favorable to granulation.

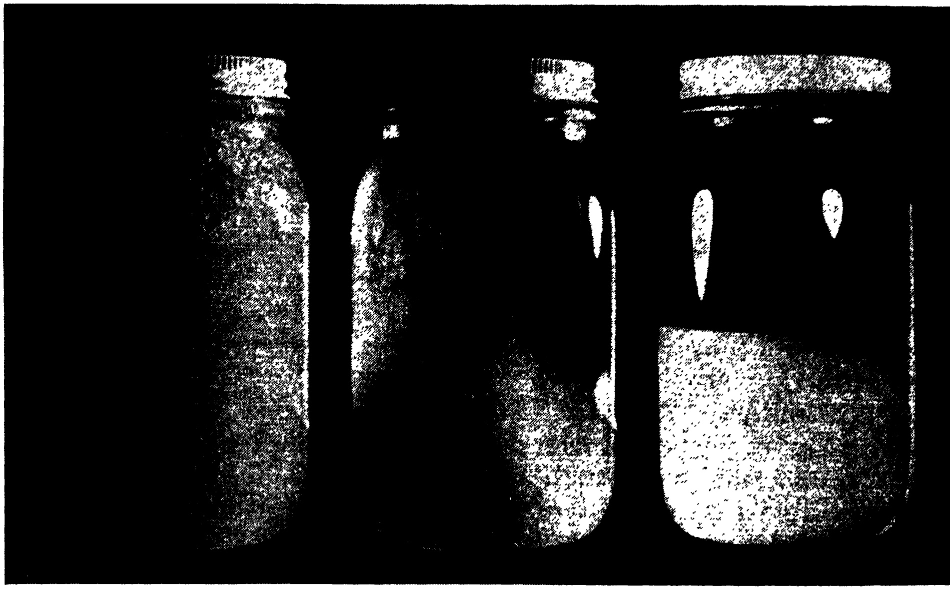


FIGURE 200. The jar of honey at left has granulated solidly. The bubblelike formation toward the top of the jar is the result of fermentation after granulation. The jar in the center represents partial fermentation. Note the large nuclei of crystals that have formed in the upper half of the honey, while the lower part is almost solidly granulated. The jar of honey at right, reported to be soybean honey, represents partial reliquefaction after previous complete granulation. Liquefaction first occurs at the top and gradually spreads downward within certain limits. The liquid portion is slightly higher in levulose, while the solid portion is higher in dextrose than the original ungranulated honey.

Although in some countries, such as Canada, marketing of honey in the granulated form has long been the common practice, it is only within recent years that any concerted attempt has been made to educate the people of the United States to the fact that honey in the granulated form is a desirable product. Previous to this time, the consumer had been educated to demand honey in the liquid form. Coupled with this fact has been the rather common but incorrect assumption that honey which has "gone to sugar" is not a desirable product because it may have spoiled. A part of this prejudice has been due to the fact that when honey once is heated to prevent or retard granulation, then any later granulation is likely to be made up of large, coarse crystals which do not have a creamy texture. Besides this is the fact that honey often may ferment after granulation with actual spoilage resulting.

The tendency of a honey to granulate is primarily dependent upon the concentration of its sugars in relation to its water content and the relative proportion of dextrose and levulose. The levulose content is higher than the dextrose content in most honeys, but in a few, such as dandelion honey in which the dextrose content is higher than that of levulose, granulation is rather pronounced and may take place even before it is extracted from the combs. On the other extreme, a honey high

in levulose and low in dextrose, such as tupelo (levulose, 48 per cent and dextrose, 24 per cent), may not granulate over a period of several years except under extreme conditions. Other examples of slow-granulating honeys are bluevine, heartsease, and sage; while alfalfa and sweet clover are examples of quick-granulating honeys.

Between these extremes are many other honeys which show a tendency to granulate even though the levulose is higher than the dextrose content, the tendency to granulate increasing with the narrowing of the difference between the content of the two sugars, with but few exceptions. For example, some honeys with a difference of only 2.5 per cent between dextrose and levulose, as in the case of sweet clover, will granulate soon after extracting.

It is a well-known chemical and physical fact that with many supersaturated solutions, sometimes something else must be done to bring about granulation or crystallization. In some solutions, agitation or jarring will start crystallization; in others a crystal of the material has to be added before crystallization will start. Thus with honey—if a quantity is made crystal-free by heating and then stored in sealed containers to prevent contamination with dextrose crystals, granulation will not occur over long periods, even if stored at temperatures favorable to granulation. This is partly proved by the tendency of honey in new combs, such as section comb honey (uncontaminated with crystals of old honey), to remain liquid for longer periods than extracted honey.

A possible source of contamination of liquid or extracted honey with dextrose crystals is the previously used extracting combs containing granulated honey. This source of contamination can be partially eliminated by returning supers after extracting in the fall to the colonies for cleaning of all the remaining honey, or by putting them on the colonies in the spring in sufficient time before the main honeyflow. The mixing of combs of granulated honey from the food chamber with those of extracting supers is also a source of dextrose crystals for seeding the new crop of extracted honey.

Dextrose crystals, like yeasts, actually float in the air, particularly in the honey house. Contamination by both of them can be prevented partially by using covered storage containers. When honey is heated sufficiently to melt all the crystals, strained, and placed in containers, the lids of the wholesale or retail packages should be put on while the honey is still hot. Reopening the containers at a later time actually may cause seeding of the liquid honey with dextrose crystals, giving nuclei for centers of granulation, and may introduce yeasts for fermentation after granulation occurs.

There are other sources of crystals and yeasts in the honey house in addition to the combs and the air. All utensils, storage tanks, and the connecting pipes are likely to be sources. Only a few dextrose crystals from the extracting of the previous season will serve to contaminate the

new crop, particularly the small portions left in cracks, seams, or depressions. Therefore, all equipment should be cleaned thoroughly before the new crop is extracted and processed.

If a given honey is likely to granulate or has been exposed to dextrose crystals, the next factor to be considered is the relation of storage temperatures to granulation. According to Dyce,[30] the temperature most favorable for granulation is between 50° and 65° F., with 55° to 57° suggested as the temperatures favorable for most honeys. Above and below these temperatures there is less and less granulation for most honeys, extending to none whatever.[31] There is only slight granulation at 75° with most honeys, and practically none at temperatures above 80°. At continued freezing or lower temperatures, granulation of honey is prevented because of the high viscosity which prevents the forming of aggregates or large crystals visible to the eye, even though minute crystals are present.

Besides the crystals in honey, other things which are said to influence crystallization are colloidal particles normal to all honeys, solid particles as pollen grains, and minute air bubbles. However, the effect of colloids and pollen grains is probably not of great significance because, if sufficient heating is used to melt the dextrose crystals, granulation can be prevented for long periods. It is entirely possible that in the introduction of the air bubbles, there is also a seeding of dextrose crystals from the air. If honey is placed under a vacuum to remove the air, granulation is delayed for a longer time, but the flavor may be reduced.

## Fermentation of Honey

Fermentation of honey is brought about by the action of sugar-tolerant yeasts upon levulose and dextrose, resulting in the formation of alcohol and carbon dioxide. The alcohol in the presence of oxygen may then be broken down by bacteria into acetic acid and water. As a result, honey that has fermented may have a sour taste. Due to the release of the carbon dioxide gas, granulated honey will show a lightened color, whitish streaks, or mottling, and if liquefied it will exhibit considerable foaming, particularly during heating. Upon standing, granulated honey will liquefy partially, eventually forming an upper liquid mass capped by a foamy layer.

Fermentation of honey often is called "honey spoilage." The degree of spoilage or effect upon flavor and quality depends upon the length of time fermentation is allowed to proceed before being stopped by heating or other treatment. Much honey spoilage by fermentation results after granulation. Inasmuch as the greater proportion of honeys granulate after

---

[30]Dyce, E. J. 1931. Fermentation and crystallization of honey. *Cornell Univ. Agr. Exp. Sta. Bull.* **528**:3-76. (19 refs.)

[31]Milum, V. G. 1939. Granulation and its prevention. *Amer. Bee Jour.* **79**:348-351. (8 refs.)

extraction and are later subject to fermentation, all honey producers and bottlers should be thoroughly acquainted with the factors affecting granulation and fermentation. Necessary steps should be taken to prevent spoilage by fermentation of any honey placed in storage.

Ordinary yeasts do not cause fermentation of honey because they cannot grow in the high sugar concentration. Spoilage by bacteria is not possible because of the high acidity of honey. The primary sources of the sugar-tolerant yeasts are the flowers and the soils.[32, 33] The soils in established apiaries have been found to contain sugar-tolerant yeasts,[34] while the air and the equipment in the honey house are contaminated with them. Similarly, combs in the hive, particularly those containing honey from the previous season, and wet extracting combs in storage may be abundant sources of yeasts.

Practically all honeys contain yeasts, or at least this should be assumed when planning for their care. The number of yeasts in various honeys will vary between rather wide limits, usually the greatest number being present in honeys with the highest moisture content. In combs from the same super, a greater number of yeasts is found in the uncapped combs than in the capped ones, the former usually having the greater moisture content due to incomplete ripening or to absorption of moisture under conditions of high relative humidity.

While Fabian and Quinet[32] suggested that, as far as honey fermentation is concerned, the critical moisture content is approximately 21 per cent, Stephen[35] indicated this is equivalent to 19.6 per cent in present tables because of changes in the methods of determination. The latter reported the greatest increase in fermentation of honeys of 17 to 18 per cent moisture. This suggests that honey fermentation may be prevented in part by allowing the bees to ripen the honey completely before it is removed from the hives. The surest method, although not absolute, is to wait until the combs are completely capped. Proper ventilation of hives provides for better ripening. When all the combs are not capped completely, contamination of the fully ripened honey may be partially prevented by separating the sealed and unsealed combs before extraction into two lots with separate treatments after extraction. Supers of honey should be stored in a dry room to prevent moisture absorption before being extracted. It should be remembered that bees may not be able to ripen fully all honey in damp weather and in late fall.

While honey with a low water content will not ferment in the liquid state, it may granulate and then later ferment if living yeasts are present.

[32]Fabian, F. W. and R. I. Quinet. 1928. A study of the cause of honey fermentation. *Mich. State Col. Agr. Exp. Sta. Tech. Bull.* **92**. (55 refs.)

[33]Lochhead, A. G. and Doris A. Heron. 1929. Microbiological studies of honey. *Canada Dept. Agr. Bull.* **116**. (New series.) (21 refs.)

[34]Lochhead, A. G. and Leone Farrell. 1930. Soil as a source of infection of honey by sugar-tolerant yeasts. *Canadian Jour. Research* 3:51-64. (8 refs.)

[35]Stephen, W. A. 1946. The relationship of moisture content and yeast count in honey fermentation. *Rep. Sci. Agr.* **26**(6):258-264. (10 refs.)

When dextrose crystals are formed, water is added to the remaining liquid portion in the proportion of 1 part of water to 10 parts of dextrose, which amounts to 9.09 per cent of the material removed from the original liquid. This disproportionate removal of solids from the liquid by granulation thus leaves an increased water content which may be sufficient to allow the growth of yeasts, resulting in fermentation. These facts indicate that fermentation may be controlled by prevention of granulation or simply by destruction of the yeasts by heating, followed by care to prevent contamination with living yeasts.

Heating honey to 145° for 30 minutes, or up to 160° F., has been found sufficient to prevent fermentation but not granulation, except for honeys having a low dextrose content. But even after granulation, fermentation does not follow if the heated honey originally was placed in containers and sealed while hot. As yeasts may float in the air, contamination of granulated honey with living yeasts may be prevented by keeping the containers sealed.

As honey yeasts, according to Wilson and Marvin,[36] are not able to grow at a temperature of 51.8° F., storage at a lower temperature could be a means of preventing fermentation. While this may not be practical, it does suggest that honey stored in an unheated house where temperatures remain cold during winter is not in danger of fermenting. But such low temperatures are favorable to granulation. This means that danger may be ahead with the coming of warm weather, or when the honey is shipped and placed in storage in the bottler's packing plant. Granulated honeys, which previously have not been heated to 145° for 30 minutes and sealed in containers while hot, and which are moved from cold temperatures to warm storage, should be processed immediately to avoid deterioration by fermentation.

Another method of preventing fermentation of honey is the addition of small amounts of certain chemicals, but only sodium benzoate at the rate of 0.1 per cent can be used in the United States and then only if so stated on the label. However, consumer objection to even a slight adulteration of a food product precludes the probable use of this method of preventing fermentation.

## Discoloration and Loss of Flavor and Aroma

Nearly all factors which change or alter the color of honey, after it is gathered and stored by the bees, also affect its flavor and aroma.

Except for the incorporation of air bubbles and particles of wax, the average honey removed from the bees and extracted soon thereafter is changed but little as it comes from the extractor. Some chance for discoloration by contamination may arise from any honey left in the ex-

[36]Wilson, H. F. and G. E. Marvin. 1931. The effect of temperature on honey in storage. *Jour. Econ. Ent.* **24**:589-597.

tractor, pipe lines, honey pumps, or storage tanks where it may have become darkened by age or by contact with iron in joints, cracks, or crevices. As a result of the action of the acids of honey with metals, particularly iron, some of the honey becomes dark and cloudy, and this in turn discolors the rest of the honey when mixed. This discoloration may be eliminated by the use of glass- or porcelain-lined containers, or largely prevented by making sure that all iron is well galvanized and by thoroughly removing all honey after each use of the various receptacles, from the extractor to the bottling tank. Stainless steel and monel metal have been found satisfactory, but both are expensive. Aluminum tanks are usable but present difficulties in fabrication. Tin-coated copper tanks and pipe lines have been used successfully.

A similar type of metal discoloration results around the lids of tin containers and those of jars where the inner seal does not prevent honey from coming into contact with the metal lid. The latter may be prevented by tight-fitting caps and by not allowing the honey to get on the lips of the jars as they are being filled. This type of discoloration is evidenced by an oily or greasy appearing substance around the inside of the lid which, upon coming in contact with the honey, forms a dark layer at the top which gradually spreads downward through the contents of the container. This is in contrast with the usual darkening in storage which occurs uniformly throughout the entire mass.

While some darkening of honey may be due to contamination from old honey or to metal discoloration, the greatest amount of damage to color of honey and to its aroma and flavor is due to the attempts to prevent granulation and fermentation by heating all or a part of the honey for too long a period, or to subsequent storage at a high temperature over a long period.

Inasmuch as it is known that heating honey may result in serious losses, observing some simple precautions will lessen these dangers. First of all, if prevention of granulation is not a factor and only fermentation is to be prevented, heating honey to 145° F. or slightly less for 30 minutes is sufficient and is not injurious if properly done. But where granulation also is to be controlled, then a temperature of 160° F. or slightly less for 30 minutes usually is required, the temperature depending upon the relative amounts of dextrose and levulose in the honey and the degree of granulation already existing at the time of processing. As the latter is due to the amount of introduced crystals together with a favorable temperature and time for formation of others, an early processing after removal from the bees will permit the use of a lower temperature.

Due care may be exercised to prevent discoloration by the use of a water jacket around the heating vat or tank and by providing agitation so that the honey will be heated uniformly. The water bath prevents the honey from coming in direct contact with the source of heat. If the water bath reaches only to about two-thirds of the height of the honey in the

inner tank and heat is applied at the bottom, very good circulation currents are established in the honey. The warm honey will rise to the surface, while the cooler or unliquefied portion, if previously granulated, will sink downward in the center.

Whatever means are taken to heat honey, after it is strained it should be put into containers while hot and the cap put on at once. Thereafter, every available method of cooling the honey should be employed. Even though artificial means of cooling are not used, considerable discoloration can be avoided by not piling the warm packaged honey in large stacks where the heat may be retained for weeks.

When such honey is not marketed at once, it should be stored at temperatures below 70° F. and never above 80°, for there is a steady rate of discoloration at higher temperatures. During warm summer months, the coolest place in the honey house is the best storage space from the standpoint of discoloration.

The identity of the constituents of honey blamed for discoloration during processing and storage at high temperatures seems to vary with different authors. Paine and Lothrop,[37] claim that the colloids of honey are chiefly responsible while others, who have removed the colloids, have found that the rate of discoloration in storage is not affected by their removal. It is sometimes claimed that overheating of honey is a cause of later discoloration, but actual experiments have demonstrated that any darkening by heating to prevent granulation and fermentation simply reduces the later rate of discoloration when the honey is stored at temperatures which cause it. Experiments reported by Ramsey and Milum[38] indicate that the brown color developed in honey during processing and storage is not due to "caramelization" but to a chemical reaction between the sugars and the proteins, particularly the amino acids in the honey.

With further studies[39, 40, 41] it was suggested that the primary cause of the excessive darkening of honey in storage is the breakdown of fructose due to its instability, after which the amino acids, liberated during heating or storage at high temperatures, unite with the aldehyde or ketone radical of the sugars resulting in the formation of substances which resemble caramel in color and flavor.

Darkening of honey in storage also is due to the combination of tannates and other polyphenolic substances with iron salts to form iron tannates. This is particularly true of honey stored in poorly tinned con-

[37]Paine, H. S. and R. E. Lothrop. 1933. Influence of colloidal constituents on the development of color in honey. *Amer. Bee Jour.* 73:23, 27.

[38]Ramsey, R. J. and V. G. Milum. 1933. The discoloration of honey. *Amer. Bee Jour.* 73:305-306.

[39]Lynn, E. G. 1935. Seasonal and storage influences upon the composition of honey. *B. S. Degree in Chemistry Thesis.* Univ. of Illinois.

[40]Becker, H. C. 1936. The effect of methods of processing and heating and of storage upon the composition and color of honey. *B. S. Degree in Chemistry Thesis.* Univ. of Illinois.

[41]Lynn, E. G., with D. T. Englis and V. G. Milum. 1936. Effect of processing and storage on composition and color of honey. *Food Research* 1:255-261.

tainers. This reaction may occur even in glass containers with a metal cap if there is any contact of the honey with the metal or if there is any seepage through the liner of the cap.

Under the subject of discoloration of honey, mention so far has been made only of factors that tend to give it a darker color. There is one factor that will reduce the rate of discoloration. If two lots of a given sample of honey are stored side by side at the same temperature but the light is excluded from one, the other exposed to the light will show a decreased rate of darkening over a period of time. However, direct sunlight might tend to darken honey because of the increased temperature.

## Summary of Recommended Measures

Because what has been said about handling and processing of honey to prevent granulation and fermentation is a rather extended story, a brief review may be advisable to recall the salient features. To produce the lightest colored extracted honey, it should be stored by the bees in combs built on new foundation or in drawn combs free from granules or crystals of old honey, as well as yeasts. After the honey is well ripened and capped by the bees, it should be extracted promptly after removal from the hives and processed and stored in crystal-free equipment and containers.

After extraction, honey should be strained while cool, heated in a water bath with agitation to assure uniform and quick heating to 160° F. (lower for certain honeys) and held for 30 minutes, then strained through sugar-sack toweling, placed in containers while hot, and sealed with airtight closures. All air bubbles and foam formation caused in these processes should be eliminated by proper apparatus. After placing in containers, processed honey should be cooled promptly and placed in storage in a dry atmosphere with a uniform temperature at any convenient and economical point below 70° F. For additional information, see Chapter XI, "Extracting the Honey Crop."

## Lack of Uniformity of Honeys

Variety in honeys as to aroma, flavor, and taste is to a limited extent a beneficial attribute because of the greater number of individual tastes that may be satisfied. However, a lack of general information by the consuming public leads to misunderstandings. The greatest disadvantage probably arises from the variable chemical make-up of honey which accounts for its reacting differently under any given set of conditions. Also, the different seasons bring variations in the honey produced resulting in a lack of understanding on the part of the beekeeper as to how to process the honey for the market. Thus honey indeed becomes a variable product. Because of the variable flavor and resultant product when used in cooking and baking, many who might be frequent or constant users of honey

have tended to use it not at all, only occasionally for variety, or as a substitute or supplement when some other sweet was not available.

It has been suggested that if means of standardizing honey could be devised, at least as far as its water content is concerned, then honey might be more widely used in some industries as, for example, in the preparation of infant foods.

## Honey as a Human Food

### Absorption and Functions of Sugars in the Human Body

Before considering any of the advantages of honey as a food, one should have some general knowledge of the food requirements of the human body. Protein or nitrogenous materials are needed for formation and repair of tissues and other body uses, while fats and carbohydrates are necessary to provide the energy required for heat and muscular work. Sugar, being a carbohydrate, is a source of energy in a concentrated form and is best fitted for assimilation by the body when supplied with other materials to dilute and to give it necessary bulk. The amount of this required dilution depends upon the amount of exertion that follows. Thus one undergoing very little exertion should take sugar in small amounts and well diluted, while an individual doing heavy and excessive or fatiguing work may take sugar in greater and more concentrated forms. It has been shown that an increase of sugar in the diet, when not too great or concentrated, lessens or delays fatigue and increases working power. Many practical tests have shown the value of sugar in the rations of men subjected to various types of extraordinary exertion. This is due


Figure 201. Honey bread is nutritional, healthful, and tasty—and keeps fresh longer on the grocer's shelves.

FIGURE 202. A delicious honey strawberry pie made from one of the many recipes available to the housewife.

to the rapidity with which it is assimilated as compared to starches and fats. This fact, together with the flavor and sweetness, undoubtedly accounts for the almost universal desire for sugar by all humans.

When cane sugar or sucrose is eaten, it must be changed in the digestive tract by the action of enzymes or ferments into the simple sugars, levulose and dextrose. Thus honey as a source of sweetening has a special advantage in that the larger proportion of its sugar content is made up of these simple sugars. While levulose is not quickly assimilated by the human body, dextrose is in the form in which sugar reaches the blood and muscles to be burned to yield muscular energy and heat. Solutions of dextrose are used for direct injection into the blood stream in any illness when food cannot be taken in any other manner.

When honey is taken into the alimentary tract, the levulose and dextrose, even though in simple form, are not assimilated immediately because the stomach does not have a marked absorbing capacity for sugar. However, a portion of any material in solution passes within a few minutes into the small intestine where, according to Cori,[42] some dextrose is absorbed immediately into the blood stream. Levulose rarely, if ever, is found in the blood stream. Before becoming a source of muscular energy and heat, levulose must first be converted in the liver to glycogen, then

[42]Cori, C. F. 1925. The fate of sugar in the animal body. I. The rate of absorption of hexoses and pentoses from the intestinal tract. *Jour. Biol. Chem.* 66:691-715.

reconverted into dextrose before being transported by the blood stream for assimilation. Thus honey taken into the human system has a distinct advantage as a source of sugars to provide muscular energy and heat because it has a combination of simple sugars which enables the body to use them over an immediate as well as an extended period without serious strain upon the body organs.

While numerous tests, as reported under "Honey in Infant and Child Feeding," have been made in which honey has been substituted for other sugars in the diet, no cases have come to attention of attempts to use honey alone as a diet. The closest approaches have been experiments of Haydak and his associates at the University of Minnesota in which cow's milk and honey were used as exclusive diets. In the first experiment, Haydak[43] subsisted for 3 months on a milk-honey mixture consisting of 100 grams of honey to each quart of cow's milk. The ability to work was normal with no sluggish or tired feeling developing. The limited clinical observations showed no loss of weight, normal bowel movements, absence of proteinuria and glycosuria, and a slight rise in hemoglobin content of the blood. At the end of the experiment, certain vitamin C deficiency symptoms were noticed, consisting of fresh blood in the feces, dryness of the skin, a hyperemic area on the gums, numbness and ulcerations of the gums, and small reddish papulae on the forehead and face, all of which were promptly cured by the addition of orange juice to the milk and honey diet.

In the second set of experiments,[44] five healthy individuals varying in age from 22 to 44 years were put on a diet consisting of a mixture of 1 quart of pasteurized milk with 100 grams of light honey. In addition, a solution containing 65 milligrams ascorbic acid and 1 milligram thiamine chloride was added daily to the diet of each individual. It was concluded that this diet proved to be adequate to support life, but not to prevent deficiency symptoms entirely. These instances are of extreme and limited diets not recommended for ordinary consumption, but they do lend support to the use of honey as a human food.

## Energy-Producing Value of Honey

In modern nutritional studies, the value of various foods is not based entirely on caloric values. However, honey often is assigned a rating of 1,481 calories, as compared to 1,815 for a pound of cane sugar, although that of honey is variable depending upon the relative moisture and sugar content. On the basis of a daily human requirement of 3,500 calories, a pound of honey would supply 42.3 per cent of the required total, and 2 pounds 7 ounces would supply the entire amount. But no human would

[43]Haydak, M. H. 1938. Living in the land of milk and honey. *Gleanings in Bee Culture* **66**:624-625. Also *Minnesota Med.* **19**:774. 1936.

[44]Haydak, M. H., A. E. Vivino, J. J. Boehrer, O. Bjordahl, and L. S. Palmer. 1944. A clinical and biochemical study of cow's milk and honey as an essentially exclusive diet for adult humans. *Amer. Jour. Med. Soc.* **207**:209-219.

want to rely upon honey for his total caloric requirements, for while honey is high in carbohydrates it would be quite deficient in supplying other food materials in the total amounts required. Whatever the amounts of vital foods contained in honey, other than sugars, they are in addition to those of sugars and are an aid in providing the total required.

### Honey in Cooking and Baking

"If you a cook of note would be,
Use honey in your recipe."
—Harriett M. Grace[45]

This subject is one that includes a world of information and countless recipes which have appeared in the bee journals and in cookbooks. The American Honey Institute, Madison, Wisconsin, now serves as a source for dissemination of such materials and the reader is referred to its publications, as well as to the bulletins and circulars issued by the home economics staffs of the various colleges and experiment stations.

Honey not only adds flavor in baking, but it has the distinct advantage that the final product, although seemingly dry upon coming from the oven, soon acquires a moist texture and remains palatable, without drying, over a longer period (Figs. 201, 202) than similar products in which cane sugar is used as the sweetening agent. This quality is due to the ability of the levulose portion of the honey to absorb and hold moisture.

Every honey producer knows countless ways in which honey may be used in menus. The following are just a few suggestions: honey iced tea, honey fruit cake, honey fudge, honey oatmeal cookies, honey-glazed baked ham, honey French dressing, and hot honey lemonade.

While tested recipes using honey are to be recommended, honey may be substituted as the sweetening agent where any recipe calls for sugar. In muffins, bread, and rolls, calling for a small amount of sugar, honey can replace the sugar measure for measure without any other adjustment. For cakes and cookies, which require a large amount of sugar, honey can be used measure for measure but the amount of liquid must be reduced one-fourth cup for each cup of honey used, or in the same proportion for fractions of a cup. Moderate oven temperatures, 350° to 375° F., are suggested to prevent the product from becoming too brown.

### Honey in Infant and Child Feeding

Honey has been used widely in infant feeding with success (Fig. 203). Numerous controlled experiments have given conclusive evidence of its value in correcting various deficiencies in infants and older children.

Dr. Luttinger,[46] a pediatrist and pathologist of the Bronx Hospital, New York, N. Y., recommended the use of honey in any condition of the

[45]Grace, Harriett M. 1947. *New Favorite Honey Recipes.* Madison, Wis. American Honey Institute.

[46]Luttinger, P. 1922. Bees' honey in substitute infant feeding. *N. Y. Med. Jour. and Med. Rec.* **116**:153-155.


FIGURE 203. Preparing a day's feeding for the baby. At 9 months, each feeding consists of 4 ounces of boiled water to which 1 teaspoon of honey and 4 ounces of condensed milk are added. (*Photo courtesy Natt Dodge*)

intestinal tract where the assimilation of starch or the disaccharides is delayed and where prompt absorption is desired. He preferred honey to alcohol, especially in bronchopneumonia, and used it in cases of summer diarrhea in the proportion of 1 teaspoon of honey to 8 ounces of barley water.

Dr. Luttinger highly recommended the use of honey in infant feeding because it does not produce acidosis, its rapid absorption prevents it from undergoing alcoholic fermentation, its free acids favor the absorption of fats, it complements the iron deficiency in human and cow's milk, it increases appetite and peristalsis, and it has a soothing effect which reduces fretfulness. Dr. Luttinger concluded that he was using honey more extensively in cases of marasmus, rickets, scurvy, malnutrition, and other conditions where formerly various sugars, cod-liver oil, and patent foods were prescribed.

Some of these attributes of honey seem to have been verified by subsequent investigators. Dr. Emerich[47] found that anemic children had a greater increase in hemoglobin content of blood when receiving honey and milk than when milk only was added to the normal diet. She attributed this increase, not to small additional calories, but to something

---

[47]Emerich, Dr. Paula. 1923. Unsere weiteren Erfahrungen mit Honigkuren im Kinderheim Frauenfelder. *Umden. Schweiz. Bienen Ztg.* **46**:136-142. (Ibid. 1932. **68**(12):616.)

in honey that acted directly on body cells, activating and strengthening them. Haydak and associates (see reference No. 20 in this chapter) concluded that "dark honey can play a role in the prevention and cure of nutritional anemia in rats, while light honey is less effective as a source of the blood-forming elements."

Numerous observers, including Rolleder,[48] Muniagurria,[49] Lahdensuu,[50] Stancanelli,[51] and Farioli,[52] in tests using honey in feeding children of various ages, found special values for honey as compared to other sugars. Included in the observed benefits were an increase in the hemoglobin content of the blood, relief from constipation, better weight gains, a decrease in diarrhea and vomiting, more rapid increase in blood sugars than after sucrose administration, better weight gains when honey was substituted for dextromaltose after faulty nutrition, and good honey tolerance with infants suffering from rickets, inflammation of the intestine, malnourishment, and prematurity.

Schlutz and his associates,[53, 54] of the University of Chicago, in tests of 11 children found that, with the exception of glucose, honey was absorbed most quickly of various sugars in the first 15 minutes following ingestion, yet it did not flood the blood stream with exogenous sugars until the fasting level was again reached. They concluded that honey should have a wider use in infant feeding.

Dr. Knott and his associates,[55] in a study of 14 healthy male infants for the first 6 months of their lives, found better calcium retention with honey than with corn sirup. However, as other factors favoring calcium retention were made more favorable, honey had less effect because each infant has an upper level of response which is optional for the storage of calcium. Their general conclusion was that honey deserves wider use in infant dietaries.

With this amount of definite evidence in the case of infants and children, there seems to be plenty of reasons for including honey, not only

[48]Rolleder, A. 1934. Untersuchungen über den Wert des Honigs für die Ernährung von Kindern. *Bienen Vater* **66**(8):281-284, 341-342. (Also *Arch f. Kinderh.* **101**:244.) (Rev. *Bee World* **15**:137; also by Schlutz, F. W. and E. M. Knott, see reference No. 54 this chapter.)

[49]Muniagurria, C. 1931. (On honey for constipation, malnutrition, enterocolitis, and dyspepsia.) *Bull. Soc. de pediat. de Paris* **29**:227. (From Schlutz, F. W. and E. M. Knott, see reference No. 54 this chapter.)

[50]Lahdensuu, S. 1931. (On value of honey over saccharose in infant feeding.) *Acta. Soc. med. fenn. duodecim.* **15**:1. (From Schlutz, F. W. and E. M. Knott, see reference No. 54 this chapter.)

[51]Stancanelli, G. 1933. (On use of honey for faulty nutrition.) *Pediatria* **41**:524. (From Schlutz, F. W. and E. M. Knott, see reference No. 54 this chapter.)

[52]Farioli, A. 1937. (On honey for infants suffering from rickets, enteritis, malnourishment, and prematurity.) *Riv. di clin. pediat.* **34**:337. (From Schlutz, F. W. and E. M. Knott, see reference No. 54 this chapter.)

[53]Schlutz, F. W., E. M. Knott, J. L. Gedgoud, and I. Loewenstamm. 1938. The comparative value of various carbohydrates used in infant feeding. *Jour. Pediatrics* **12**:716-724.

[54]Schlutz, F. W. and E. M. Knott. 1938. The use of honey as a carbohydrate in infant feeding. *Jour. Pediatrics* **13**:465-473.

[55]Knott, E. M., C. F. Shukers, and F. W. Schlutz. 1941. The effect of honey upon calcium retention in infants. *Jour. Pediatrics* **19**:485-494.

in the diets of infants and children, but in the diets of adults as well, and particularly those who are undergoing vigorous exercise under exacting conditions. Formulas which gave beneficial results in infant feeding may be found in the references[56, 57, 58, 59] cited in the footnotes.

### Honey for Athletics and Strenuous Occupations

Honey has been used with beneficial results by athletes in football, basketball, track including marathon running, swimming, wrestling, and 6-day bicycle racing. It has been used as a source of energy in climbing Mt. Ranier and in crossing the Grand Canyon. Honey was used before and during the attempts of deep-sea divers to recover the gold of the sunken Lusitania. It is explained that honey provides a carbon background for the oxygen to burn upon, preventing the burning of body tissues.

Honey, as explained elsewhere, is readily assimilated, giving athletes a quick source of energy and enabling them to recuperate rapidly from severe exertion with less evidence of fatigue. The latter is particularly true when taken soon after an athletic event. Honey may be used either alone or diluted with orange juice.

### Honey for Diabetes

Beekeepers have reported numerous cases of individuals suffering from diabetes who have recovered by using honey as their source of sweets. Patients who are under the care of a physician and not too far advanced may use honey in small amounts at first, after which the amount may be increased if sugar does not show in the urine or blood. There is some indication that honeys from special plant sources are more desirable, particularly if of high levulose content. Because the body is unable to utilize levulose until it is changed into glycogen and then into dextrose, a slower infiltration of dextrose into the blood stream is provided. As honey also contains dextrose which is immediately available to oxidation, this portion of honey can cause overconcentration of sugar in the blood. Therefore, the use of honey in cases of diabetes should be under the direction of a physician.

### Honey Sensitivity

There are numerous cases of persons who seem to be unable to eat honey without undergoing severe cramps which sometimes may be relieved by drinking water freely. The exact reasons seem to vary with different individuals with the blame being ascribed either to unripe honey,

---

[56] Jones, W. Ray. 1928. Milk modified with honey for the baby. *Amer. Bee Jour.* **68**:69.

[57] Nielsen, Mrs. Benjamin. 1935. Honey for infant feeding. *Gleanings in Bee Culture* **63**: 591-593.

[58] Root, H. H. 1941. Honey for babies. *Gleanings in Bee Culture* **69**:76-77, 123.

[59] Schultz, Mrs. A. J. 1941. Infant feeding formula from an extensive experience. *Amer. Bee Jour.* **81**:56.

to the osmotic action of too much undiluted honey taken into the stomach, to something in honey that is destroyed in the preparation of food, to the presence of beeswax in honey, to the pollen or its soluble portions dissolved in honey, or in some cases to strange honeys from particular areas or different plant sources.

The remedy seems to be to leave honey alone for a time hoping that the sensitiveness will disappear and later to try honey from some other source, starting with only small amounts. Too much unripe honey, at one time, has brought many a small boy to the point of digestive complaint.

## Other Uses of Honey

### Honey for Hay Fever

Although further experimental work is needed, there seems to be some evidence that honey, gathered in the locality of the hay-fever sufferer and containing the pollens causing the particular types of hay fever, is of value in alleviating its severe symptoms. While some have attributed the results to the chewing of the wax comb, it appears more likely to be the pollens included in the honey. In fact, some beekeepers have established a trade by collecting pollens from various seasons and adding them to the honey according to the hay fever from which their customer-patients were suffering. Large quantities of pollen are required, one suggestion[60] being 1 ounce of pollen to 11 ounces of honey, this giving relief to 65 to 70 per cent of the patients over two seasons.

### Antiseptic Properties of Honey

If the vegetative or nonsporeforming bacteria which cause human diseases get into honey, the moisture content of bacteria is absorbed by the levulose of the honey, which causes them to dry up and die in a short time. Thus honey is a very poor medium for transmission of human diseases. It does not necessarily follow that honey consumed as food will destroy germs in the body, but there is evidence that honey is valuable in increasing the general health and resistance of the patient.

The only known exception to the ability of honey to destroy the spores of introduced bacteria is *Bacillus larvae* which causes American foulbrood of the bee larvae. *Bacillus larvae* does not affect humans and adult bees when honey containing its spores is used as food.

Honey alone or with butter has been used with excellent results in the treatment of severe burns with no blisters resulting. Honey mixed with cod-liver oil makes a salve which has been found to be effective for alleviating the pain and hastening the healing process of all kinds of wounds, including cuts, bruises, lacerations, and sore nipples.

---

[60]Powell, J. W. 1933. Honey and pollen for hay fever. *Amer. Bee Jour.* 73:391.

### Honey as a Plant Stimulus

In tests made in Oklahoma,[61] honey stood well up in the list of growth substances for plants. When seed of stock beets were soaked for 4 hours in a solution of 1 part honey to 99 parts water, a yield of 16.1 tons per acre resulted as against 5.6 tons when untreated seed was used. At Ottawa, Canada, Oliver[62] reported that higher percentages of the cuttings of Thuja and chrysanthemums were rooted with a larger number and greater length of roots for each cutting when they were treated with honey. In comparison with commercial preparations, honey was rated equal to the best. When shipping fruit trees with no soil on the roots, Curtis[63] recommended dampening of the roots and any small limbs with thick honey, followed by rolling in cloth and paper.

Honey has been used by bacteriologists of the University of Wisconsin[64] in making manatol. Manatol is used in preparing bacterial cultures for the inoculation of the seed of clover, alfalfa, and similar plants.

### Honey for Feeding Animals

Honey is reported by various writers to have been used successfully in the feeding mash of race horses, using a strong, dark honey; in feeding dairy cows at the rate of 4 ounces for each cow per day, making the animals healthier and increasing the milk supply; with hay, in lack of roots, at the rate of 1 pound each day for dairy cows, keeping up milk flow and increasing their weight; and with grain in fattening steers. It has been found satisfactory in poultry mash. Many species of fish were found to thrive on a diet mixture of honey and flour, gaining extra weight in comparison to fish on ordinary diet.

Honey has been used successfully in the treatment of acetonemia, a disease of cows at calving time. The symptoms commonly appear from 2 to 2½ weeks before calving time, the cows refusing to eat. Molasses as a drench or in feed, plus glucose in the veins, usually is used in the treatment. A dairyman has reported the curing of a cow with honey alone given as a drench. Approximately 4 gallons of honey were used in the proportion of 1 quart of honey to 1 quart of water twice daily for a period of 16 days.

### Miscellaneous Uses of Honey

Honey is a common ingredient of cough sirups, particularly honey and tar combinations. Honeys with strong minty flavors, such as horsemint, are sought by some manufacturers. A satisfactory homemade cough sirup can be prepared by mixing and simmering for 15 minutes 1 cup of

[61] Ireland, J. C. 1942. Influence of honey on growth. *Amer. Bee Jour.* **82**:313.
[62] Oliver, R. W. 1940. Honey as a stimulant to the rooting of cuttings. *Amer. Bee Jour.* **80**:158.
[63] Curtis, Chester. 1937. A new use for honey. *The Australasian Beekeeper* **39**(2):44.
[64] 1927. Another possible use for honey. *Wisconsin Beekeeping* **4**:126.

honey, preferably dark honey, with 1 teaspoon of ginger and the juice of one lemon.

In Europe, honey has been widely used for making various beverages which are reported to be of good quality and high alcoholic content. The best results are secured when specific types of yeasts are used to produce alcoholic fermentation, the first step in the process of producing vinegar by those not interested in arresting the process at the wine stage.

Honey seems to have earned a niche in the beauty parlor because it has been described as a 15-minute facial pack for cleansing the face,[65] having a beneficial effect, firming the face muscles, and having an astringent as well as a bleaching effect. It is a prime ingredient of a facial cleanser for oily skins. Honey is used in hand lotions. One editor[66] reports that the juice of one medium-sized lemon with 1 tablespoon of honey taken each morning before breakfast aids in reducing weight and keeping the figure, and helps to keep the complexion clear.

Honey has been found to have a tenacity and affinity to hold for more than 4 months a synthetically produced scent known as mercaptan as a repellent for rats and mice.[67] It also has been used as a spray adherent combined with steam cylinder oil for control of greenhouse red spider.[68] Having most of the properties of glycerine, it has been used successfully as a shock absorber in Model A, Ford cars, and as the center for golf balls by one prominent manufacturer.

Honey has been used in curing pipe bowls and as an ingredient of cigarette and chewing tobaccos to improve flavor and texture, and to keep the tobaccos moist. It has been used to keep chewing gum from drying out and it also has been used in the curing of hams.

In cold storage of egg yolks, or yolks with the whites, Oliver[69] found that the most effective treatment to prevent them from becoming gummy and difficult to use was to add 1 tablespoon of honey to every 2 cups of eggs, stirring gently but thoroughly.

---

[65] 1942. Honey in the beauty parlor. *Amer. Bee Jour.* **82**:401.

[66] 1938. A beauty hint. *Amer. Bee Jour.* **78**:101.

[67] Clausen, D. F. and L. A. Ford. 1942. A new use for honey. *Gleanings in Bee Culture* **70**:22.

[68] Pfister, Grover. 1940. Honey for controlling insects. *Farm Jour.* Aug. p. 22.

[69] Oliver, A. W. 1941. Freezing and storing meat, poultry, and eggs. *Ore. State Col. Ext. Circ.* **373**.

# XVI. *Marketing the Honey Crop*

BY R. B. WILLSON*

THE United States is the largest honey-producing country in the world. According to official government figures, an average annual honey crop is just about 200,000,000 pounds. It might help to visualize this enormous quantity of honey by stating that if loaded in standard 40-foot freight cars, 36,000 pounds to a car, it would require a freight train 47 miles long! Except for the honey that is consumed by the producer and his family, or given away by him, all of this honey goes to market.

In general terms half of it is sold by the producer directly to the retailer, the household consumer, or the small industrial user, such as the local baker. It is sold through sales by mail, by door to door canvassing, or from roadside stands. This half of the honey crop is produced by an estimated 80 per cent of the 600,000 beekeepers in the United States.

The other half, which might be called the honey of commerce, is in the main extracted honey produced by beekeepers operating hundreds, and even thousands, of colonies of bees, and who depend on their bees for a major part, if not all, of their income. This honey of commerce is sold by the producer to bottlers who package it, to large industrial users who incorporate it into products, such as bread or candy, or to dealers who resell it as it is or reprocess it, according to the requirements of the customer. The honey usually goes to market in the standard bulk container for this commodity—the 5-gallon tin can which holds 60 pounds net weight of product. A very heavy percentage is shipped in full truck loads of 20 thousand pounds or minimum carloads of 36 thousand pounds, according to rail freight regulations. The small portion of the crop which is section comb or bulk comb honey will be treated separately.

## Marketing Extracted Honey

There are some large producers who bottle honey and successfully market it, but they are few in number. Most beekeepers do not have either the equipment and plant or the temperament to meet the exacting

*R. B. Willson. President, R. B. Willson, Inc., New York City. Formerly associated with the John G. Paton Company, New York. Many years' experience in the honey marketing business. Chairman of the Honey and Pollen Plants Committee of the National Federation of Beekeepers' Associations. Formerly extension apiculturist, Mississippi State College and Cornell University.

requirements of modern large-scale selling of consumer packages, and so they are content to produce the crop and leave the ultimate disposition of the honey to others. More and more, the selling of their honey is being done by the producers' own co-operative associations which now sell more than 30 per cent of the commercial honey of America. The fact that most of this is sold in household-consumer packages enables the management to net the highest possible return for their members.

Factors that affect the quality of honey also influence its marketability, and they start to manifest themselves right in the apiary. There is little a beekeeper can do about the color and flavor of the honey as the bees make it, for until then it is a pure and natural product. But from then on it is important how it is handled, both in removing the crop from the hives and preparing it for market. *The complete satisfaction of the consumer of that honey should be the guide to its handling for market.* The following cardinal points should always be observed:

1. Honey should never be extracted until it is thoroughly ripened by the bees, which in most locations requires that it be almost completely capped.

2. Honey is extremely sensitive to odors and can be quickly and irretrievably contaminated. Rank or excessive smoke due to oily waste or old rags, or anything else that gives off disagreeable fumes, should not be used when working bees in the honeyflow. Special care should be used when removing supers with carbolic acid, which should always be pure, and should be left on the colonies for only a minimum of time to accomplish driving the bees from the combs.

3. The different varieties of honey, whenever possible should be carefully segregated before extracting, even when the producer is deliberately planning to blend his honeys to get a certain flavor for which he has a market.

4. After extracting, all honey should be thoroughly strained through sugar-sack toweling or mesh cloth strainers (see U. S. Grades in this chapter), not merely through cheesecloth, and allowed to settle in tanks. A minimum of heat should be used—130° F. for packaging in bulk containers and 150° F. for household-consumer packages.* Where pumps are used, the producer should ever be on the alert to guard against leaks that churn minute air bubbles into the honey—bubbles so small that they are almost impossible to get out and which cause a cloudy or turbid appearance (see Chapter XV, entitled "Honey").

## Grading Honeys

Trading in honey is generally begun by the producer who offers honey according to the floral source, such as clover, orange, catsclaw, or

*While higher temperatures, 145° to 160° F. (see Chapter XI, "Extracting the Honey Crop," and Chapter XV, "Honey,") are usually recommended, lower temperatures are advisable when honey is handled in large quantities in commercial processing.

tupelo. When the buyer is interested, especially the dealer in bulk honey, he wants an actual sample—the very best way to avoid misunderstandings between buyer and seller. Because of the difficulties and misunderstandings involved, there has been a real need for standarized grades by means of which honey can be clearly defined in words. Although they are not in general use in trading of bulk honey, the following grades have been established by the government for use in labeling retail packages.

*United States Grades*

United States standards for grades of extracted honey,[1] effective March 15, 1943, specify three grades of extracted honey: U. S. Grade A or U. S. Fancy, U. S. Grade B, and Off-grade honey.

*U. S. Grade A* or *U. S. Fancy* extracted honey may be of any color, shall be clean, and shall be free from damage caused by turbidity, overheating, fermentation, honeydew, objectionable flavor or odor, or other means. The honey shall be well-ripened, weighing not less than 11 pounds 12 ounces per gallon of 231 cubic inches at 20° C. (68° F.). Expressed in other equivalents, extracted honey shall conform to the following:

Brix reading—not less than 79.8° at 20° C.
Baumé reading—not less than 42.49° at 60° F.
Refractive index—not less than 1.4900 at 20° C.
Specific gravity—not less than 1.4129 at 20° C.

Crystallized honey of this grade shall be uniformly granulated, smooth and fine in texture, and when liquefied at 130° F. shall meet all other requirements of U. S. Grade A or U. S. Fancy.

*U. S. Grade B* may be honey of any color, shall be fairly clean, shall be free from damage caused by turbidity, overheating, fermentation, honeydew, objectionable flavor or odor, and other means, and shall conform to Grade A specifications of weight and other equivalents. Crystallized honey of this grade shall be uniformly granulated, fairly smooth, medium to fine in texture, and when liquefied at 130° F. shall meet all other requirements of U. S. Grade B.

*Off-grade* honey is that which fails to meet the requirements of U. S. Grade B.

*Explanation of Terms*

"Density"—shall be determined by Brix or Baumé hydrometer or by refractometer read at the temperature for the instrument used, or by weighing in a standard measure.

"Clean"—honey at least as free from foreign material, wax, propolis, bees, parts of bees, and dirt as honey that has been strained through standard bolting cloth of 86 meshes per inch at a temperature of not more than 130° F.

[1] 1943. *United States Standards for Grades of Extracted Honey*. U.S.D.A. Food Distribution Administration.

"Fairly clean"—honey at least as free from foreign material as honey that has been strained through standard bolting cloth of 23 meshes per inch at a temperature of not more than 130° F.

"Damage"—any injury or defect that materially affects the appearance, edibility, or shipping quality.

"Serious damage"—any injury or defect that seriously affects the edibility or shipping quality of the honey.

"Turbidity"—cloudiness caused by pollen grains, air bubbles, wax particles, or other substances that detract from the clearness of honey.

"Objectionable flavor or odor"—any flavor or odor from a floral source, taint or smoke, or other source that materially affects the edibility of honey. Nectar gathered from plants, such as bitterweed, often imparts a disagreeable flavor, materially injuring the quality.

*Color Grading*

Many beekeepers object to color grading, insisting that flavor is of first consideration. The wholesale buyer, however, insists that honey be graded as to color. Samples of honey shall be considered of one class if not more than 5 per cent by count of the containers examined have honey of a different color, provided that no sample indicates a reading below the next color class. The standard colors as indicated by the Pfund color-scale instrument are as follows:

| | | | |
|---|---|---|---|
| Water-white | 0 | to | 8 |
| Extra-white | 8 | to | 16.5 |
| White | 16.5 | to | 34 |
| Extra light amber | 34 | to | 50 |
| Light amber | 50 | to | 85 |
| Amber | 85 | to | 114 |
| Dark | Readings of 114 and over | | |

The Pfund scale readings are expressed in millimeters. The Pfund Grader is a development of the Bee Culture Laboratory and is the color grader recognized by U. S. standards (Fig. 204). It can be obtained from scientific houses, but its cost is prohibitive to most beekeepers. Those wishing to grade accurately the color of their honey may submit samples to state and government sources. The majority of beekeepers, however, grade honey by eye as white, light amber, amber, and dark amber, and this is usually sufficiently acceptable to be satisfactory.

## Blending Honeys

Honey from each floral source has a distinct flavor and color and in some instances a characteristic body. These facts are well known to the producer, but the consumer expects, from year to year, to buy honey of a uniform quality to which he has become accustomed. This is an important factor in the merchandising of honey and many local markets are upset because honey within a given locality varies from season to season. Prob-

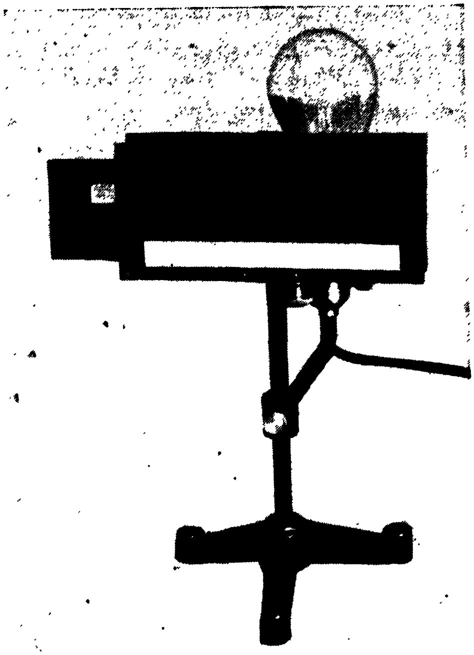


FIGURE 204. The Pfund grader is the standard instrument for color grading of honey. (*Photo courtesy Division of Bee Culture*)

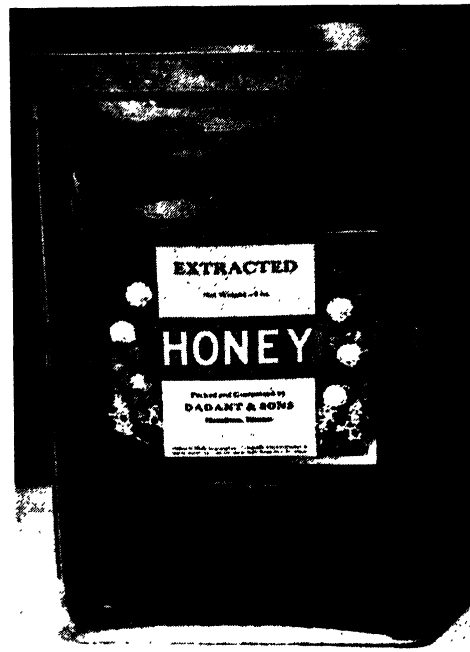



FIGURE 205. The 5-gallon tin can containing 60 pounds net weight of honey is the usual wholesale container.

ably no other factor contributes more to retarding consumer demand. The large packers and even the small producers recognize the importance of uniformity. More and more, they are resorting to the purchase of other honeys for blending so as to bring the quality of their honey to a standard flavor, color, and body.

Underlying this practice is the acknowledged fact that wide variations in the quality from year to year in any given product or brand are ruinous to its reputation. Whereas minor seasonal variations are to be expected, they can be greatly minimized through careful blending.

## HEATING HONEY

In honey house operations after extracting, in the liquefying of granulated honey, and in the blending of different varieties, the heating of honey is necessary.

Much honey is ruined every year through the improper application of heat. Although the type of equipment used in this process may vary greatly, there are two underlying principles involved in the heating of honey that should always be observed. In the first place, flame or live steam should never be applied directly to the container holding the honey because this will only tend to burn it. Rather, heat should be applied indirectly. This makes practical the use of the jacketed tank, the outer

tank or jacket being filled with water to which the heat is applied. The other principle to observe is that where crystallized honey is being heated in some ovenlike arrangement with dry heat, the containers should be inverted to permit the honey to run out of the opening into a receiving tank as fast as it is melted. In this instance, liquefying is accelerated by the introduction into the oven of a small amount of steam because the conductivity of heat is far greater when air is moist than when it is dry.

In commercial packing of honey, the highest temperature that should be reached is 150° F. if optimum results in flavor retention, the preservation of enzymes, and the maintenance of the lightest possible color are to be obtained. All points at which heat is applied should be thermostatically controlled so that the honey cannot go above this temperature. Such procedure assures liquefaction of all crystals and, for all practical purposes, eliminates the trouble of later granulation.

Whenever honey is heated, it is desirable that it be stirred gently to attain a uniform temperature throughout the mass. In commercial packing, all honey tanks should be equipped with slow-driven power agitators at the bottom of the tanks. The mixing tanks should be wide rather than deep to allow air and foreign materials to reach the surface more readily during the settling period. The bottom of the tank should be funnel-shaped rather than flat so that foam on the top gathers in concentric rings on the bottom of the tank as the honey is drawn off.

Regardless of whether honey has been strained or not, it should again be strained just prior to filling the containers, either for retail or for

FIGURE 206. Clean, attractively labeled glass jars make the best container for liquid extracted honey.

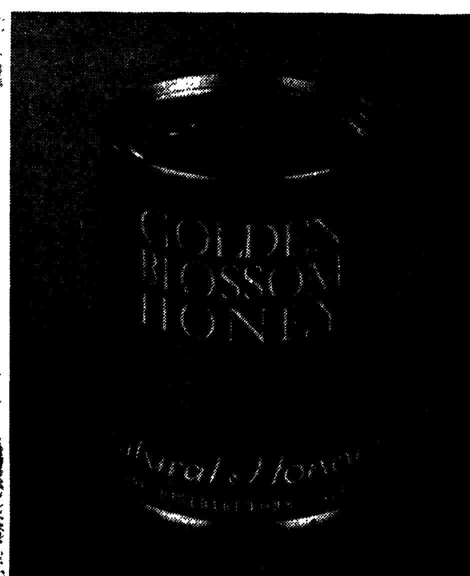


FIGURE 207. Vacuum-packed liquid honey in a lithographed tin container—a beautiful package. (*Photo courtesy John G. Paton Co.*)

wholesale consumption. A strainer, therefore, should be in the line just prior to the filling operation. To achieve U. S. Grade A or U. S. Fancy for cleanliness, the strainer should be 86 meshes to the linear inch, which gives to the honey a cleanliness to satisfy the most exacting demands.

### Filtering Honey

It is a common practice in the United States today to pass honey through plate filters, first having mixed the honey with a given portion of diatomaceous earth. The resultant honey has an artificial brilliance which doubtless gives it a certain eye appeal. Nevertheless, it is a questionable practice inasmuch as it robs the honey of from one-third to almost half of its vitamin content and a considerable amount of its delicate flavor.[2]

It still is undetermined whether honey that has been filtered with activated carbon, or any other substance that removes both color and flavor, could be sold as honey inasmuch as the U. S. Food and Drug Administration has thus far not passed on this product.

### Wholesale Containers

Assuming that methods and equipment have in no way injured the honey, the producer is now ready to pack a first-class product. Unless he is a small producer who can pack his entire crop at one time into retail packages, he will pack most of his crop in the standard 5-gallon square tin (Fig. 205) with a screw cap (preferably the 3-inch opening, although the smaller 2½-inch cap has supposedly been standardized by the industry). If he is going to sell his honey in these bulk containers on the open market, he should always use new cans. Even if he has customers who do not object to used cans, or if he is shipping his honey to his own cooperative association, it is questionable economy to reuse these containers inasmuch as many cans split seams in transit and the contents are lost.

Railroads and common carriers require cans to be cased, and wooden cases were specified until about 1935, the common case holding two cans of honey. More recently, common carriers have accepted the corrugated fibre carton which is satisfactory for solidly granulated honey, but falls far short of giving complete satisfaction when shipping liquid honey long distances, as any receiver of carloads of honey will attest. They do not stack well and offer insufficient protection when tiering. Light or heavy damage can be anticipated in all long hauls by common carriers of liquid honey cased in corrugated fibre containers.

Some southern and foreign honeys are shipped in 50 to 55-gallon wooden barrels and steel drums, the latter being the better containers because they rarely leak. However, when steel drums are used, they should be coated inside with paraffin or beeswax to prevent the honey from coming into contact with the iron, which produces iron tannates

[2]Haydak, M. H., L. S. Palmer, M. C. Tanquary, and A. E. Vivino. 1942. Vitamin content of honeys. *Jour. Nutrition* 23(6):581-588.

that quickly blacken the whole mass of the honey. Wooden kegs, containing 160 pounds net weight each, are common containers for eastern buckwheat honey, and are preferred in the trade where they are used.

### Retail Packages

The available trade outlet often dictates the size and type of container in which honey should be packed for the consumer. Many find the 1-pound glass jar the best package for their trade (Fig. 206), while others find the 5- and 10-pound glass or tin containers most satisfactory (Fig. 207). Glass jars are available in various sizes, the 2, 5, and 8 ounce, and 1, 1½, 2, 2½, 3, 5, and 10 pound being standard. The sizes and styles of glass containers have been fairly well standardized in this country.[3] Tin containers are available in sizes of 2½, 5, and 10 pound, with plain tin containers generally used, although the more expensive lithographed containers are also popular.

Large packers of honey have designed special containers according to their own ideas. The beekeeper, who is unable to finance the cost of molds and dies for special containers, satisfies his requirements with the assortment of containers generally available.

With the exception of the lithographed tin, all of the glass and tin containers require labels. Because a private label is expensive, most producers use the stock labels available on the market which can be imprinted to their likings. The size and design of the label should conform to the size and style of the honey container. Labels for glass containers should not be too large or they will hide the attractiveness of the product. Whenever possible, it is advisable to select a label not generally used by others in the same marketing area.

## Marketing Comb Honey

Section comb honey requires careful preparation and grading before being packaged for market. The wood of each comb honey section must be cleaned thoroughly of propolis and other adhering materials. The cleaning is usually done by scraping the individual section (Fig. 208) with a sharp knife or a razor blade. The work is performed over a box or tray into which the scrapings drop. Remaining spots or stains may be removed with sandpaper.

### Grading Comb Honey

There are three grades for comb honey: U. S. Fancy, U. S. No. 1, and U. S. No. 2, with several colors in each grade. For detailed specifications of the grades of section comb honey, the producer is referred to Revised

[3] 1941. Containers for Extracted Honey. *Simplified Practice Recommendation R-156-41.* Washington, D.C. U.S. Government Printing Office.

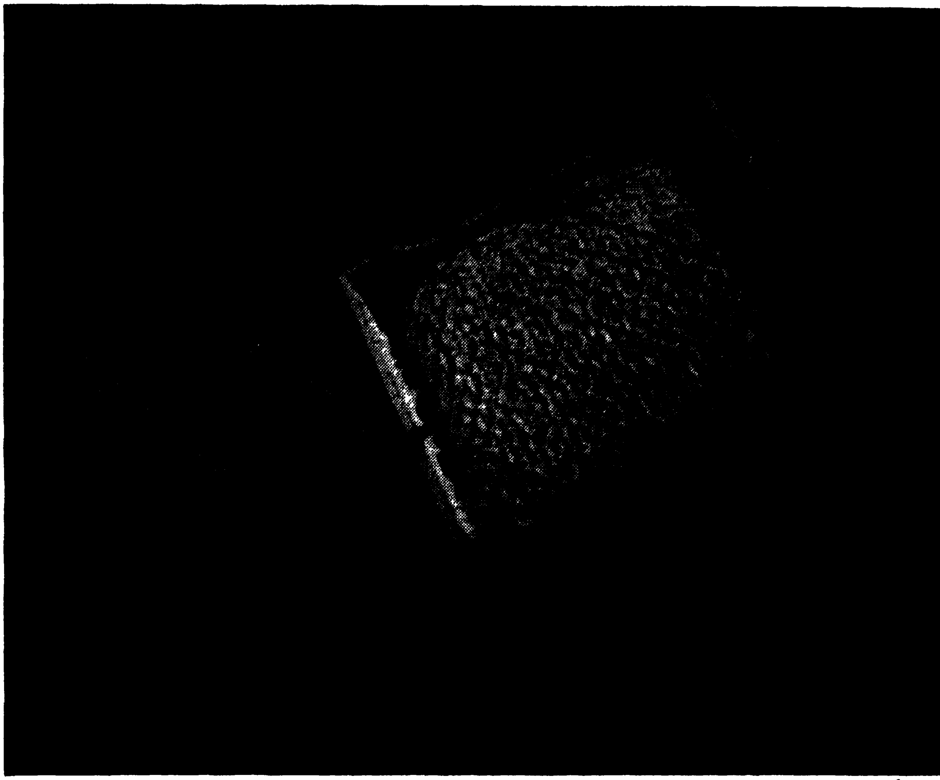


FIGURE 208. This beautiful section of comb honey is being cleaned carefully of propolis and beeswax before being sent to market.

Circular 24 which can be obtained from the Superintendent of Documents at a cost of 5 cents.[4] The official color chart, "Color Standards for Grades of Comb Honey," may also be purchased from the same source at a cost of 15 cents. Producers will find the chart of great value in color grading of comb honey.

*U. S. Fancy* comb honey is a strictly high-grade product having a minimum net weight of 12 ounces. Depending on the season and the skill of the beekeeper, from 25 to 60 per cent of the salable comb honey which he has produced will fall in this class, the other 40 to 75 per cent being U. S. No. 1 grade.

*U. S. No. 1* comb honey has a minimum net weight of 11 ounces, is slightly inferior in quality to U. S. Fancy, but is equal to it in edibility. *U. S. No. 2* comb honey has a minimum net weight of 10 ounces, is usually decidedly inferior to U. S. Fancy or No. 1, and should never be shipped to the open market, but should either be consumed at home or sold locally.

[4] 1933. United States grades, color standards, and packing requirements for honey. *U.S.D.A. Circ.* 24. Revised.

Section comb honey should be graded in a well-lighted room with the operator preferably facing away from the light. Direct sunlight or artificial light should never be used. Each grade is placed in a separate pile in a preliminary grading, and the final grading then is done, preferably by one person to avoid variations. Having a large number of sections of comb honey in each grade from which to select, there is better opportunity to fill each shipping case with comb honey that is more uniform in weight and shades of finish. Each section should be stamped with the grade, color, and net weight. Sections with only a few cells of pollen should be sold as culls, and those with considerable pollen should not be marketed. For a method of handling unmarketable sections, see Chapter XIII, "The Production of Bulk Comb Honey."

### PACKAGING COMB HONEY

While section comb honey is often sold to the consumer without any wrapping, it is advisable to package it in some manner, either in plain or printed cellophane wrappers or in individual cartons with or without cellophane windows (Fig. 209). The individual sections are then packed in corrugated cases for shipping. These cases contain 24 sections of comb honey and are available in either single-tier or double-tier styles. The wood shipping case with a glass front, which formerly was used, has been replaced by the less expensive corrugated fibre carton. When comb honey is to be delivered to a distant market, it should be shipped before cold

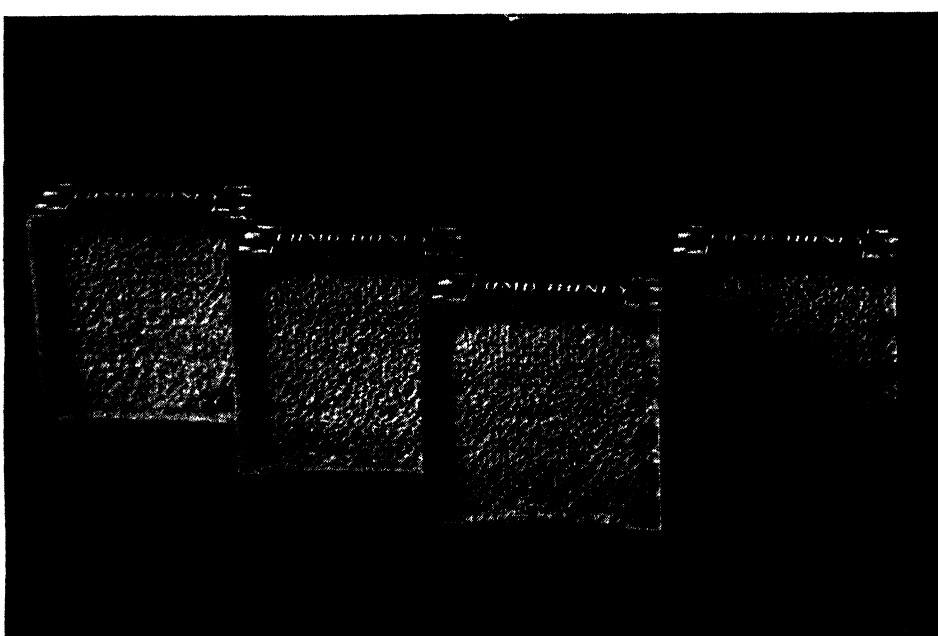


FIGURE 209. Sections of comb honey, attractively wrapped in cellophane, always find a ready market.

weather to lessen the possibility of breakage. Crated "carriers" which hold several cases further tend to reduce breakage in shipment.

## Marketing Chunk Honey and Cut Comb Honey

Chunk honey consists of one or more pieces of bulk comb honey placed in a container with the remaining space filled with liquid honey, the correct proportion being 40 per cent or more of comb honey with 60 per cent or less of liquid extracted honey. Usually the pieces of comb honey are cut as long as the depth and as wide as the mouth of the container. This package satisfies the desire for comb honey and accomplishes the sale of much extracted honey at the same time. Particularly in the South, chunk honey is a very popular package. The chief difficulty encountered in marketing chunk honey is that the liquid honey may granulate later, making it necessary to replace those containers with freshly packed chunk honey.

Chunk honey can be packaged either in glass or tin containers, but the glass container generally is preferred. The container should have a wide mouth for ready packing and removal of the comb honey. It is especially important that the label should not be large, thus detracting from the attractiveness of the product.

Cut comb honey is bulk comb honey cut into pieces and allowed to drain, or the cut edges extracted, before being wrapped or packaged in some manner to resemble section comb honey. Inasmuch as bulk comb honey is somewhat easier to produce than section comb honey, and the packaged product of cut comb honey is generally as acceptable to the consumer, this product is increasing in popularity (see Chapter XIII, "The Production of Bulk Comb Honey").

## Marketing Granulated or Creamed Honey

Honey sold in this form should be either of a kind that granulates to a fine, soft, smooth body, or should be prepared as described in Chapter XV, entitled "Honey." Honeys which granulate to a hard solid mass, unsuitable for spreading, or granulate partially or not at all, should not be used for this purpose. Granulated or creamed honey may be packed in glass or in paper containers and should be labeled attractively.

In Canada and in Europe, the consumer is accustomed to purchasing honey in granulated form in 5- and 10-pound tin pails.

## The Marketing Problem

Honey producers enjoyed a tremendous demand for honey from 1942 until late in 1947 due to an acute shortage of sugar brought about by the war. When honey was finally removed from price control in 1946 with

sugar still in short supply, the price of honey more than doubled. When sugar became abundant again in 1947, honey declined in price to about its wartime controlled level within 6 months.

Early in 1948, it became obvious that there was a large supply of strong-flavored honey that was not moving to market and the U. S. Government was induced to buy almost 11 million pounds for European relief. Table-quality honey also was not moving well, indicating that the per capita consumption of honey was not much, if any, better than in prewar years.

These developments outline sharply that there is a real marketing problem for honey in the United States. It is indeed important because of the great necessity of an abundance of bees being kept throughout the land to provide for the all-essential function of pollination, without which our agricultural economy would have to undergo drastic changes. To have bees, beekeepers must have a good market for honey—and that is a basic problem for the entire nation.

The precipitous return to low prices and slow demand for honey, due largely to the return of a normal supply of sugar, has been accentuated by two factors that have to do with imports and exports.

### Imports and Exports

Prior to 1941, the United States imported virtually no honey. We brought in and consumed the crops of Puerto Rico and Hawaii, but imports from other countries were negligible. During the war and until February, 1948, exclusive of those possessions, we imported the following quantities of honey according to U. S. Government figures:

| | |
|---|---|
| 1942 | 20,048,000 pounds |
| 1943 | 36,654,000 pounds |
| 1944 | 23,620,000 pounds |
| 1945 | 19,654,000 pounds |
| 1946 | 19,935,000 pounds |
| 1947 | 19,329,000 pounds |

The importation of honey during the war period was extremely important to the general welfare of the American honey industry because it was only through this that the industrial user was kept supplied with honey. At the expiration of the war, Latin American honey normally would have gone once again to Europe where it formerly went. Although European countries bought freely of Western Hemisphere honey shortly after the war, their dollar balances became so low that, by early 1947, all countries required import licenses and in most no exchange for purchasing honey was permitted. As a result, Latin American honey continued to be sold to American markets.

Prior to the outbreak of World War II, the United States had been selling large quantities of its honey in Europe. The decade ending with 1937 shows that American exports of honeys to Europe averaged 4,537,000

pounds annually. We are, therefore, normally an exporting nation. The U. S. Department of Agriculture gives the following quantities exported during this period:

| | |
|---|---|
| 1928 | 10,751,000 pounds |
| 1929 | 8,675,000 pounds |
| 1930 | 3,686,000 pounds |
| 1931 | 4,183,000 pounds |
| 1932 | 4,720,000 pounds |
| 1933 | 6,158,000 pounds |
| 1934 | 1,950,000 pounds |
| 1935 | 1,579,000 pounds |
| 1936 | 1,127,000 pounds |
| 1937 | 2,542,000 pounds |

Consequently, with our own crop plus Latin American imports, and with virtually no honey being exported because of the above reasons, our marketing problem has been greatly accentuated. The American producer can expect this situation to continue pending European recovery which will permit them again to buy Latin American honey plus a normal amount of the U. S. crop, until a higher tariff is placed on foreign honey to restrict its importation, or until the United States finds greater use for honey at home.

## The Home Market

Whoever sells honey must expect to service the trade constantly with an attractive, high-quality, uniform product, skillfully advertised and merchandised at current price levels. It is only when departures are made that the seller, whether he be the producer or the packer, fails to be an asset to the honey industry.

The importance of a clean, high-quality product in a suitable container attractively labeled is understood by everyone, but the importance of constant service to trade outlets seemingly is not understood, although it is very important in the development of a honey market. While the sale of honey directly to the consumer by the producer is to a certain extent seasonal, attempts should not be made to supply more retail trade outlets than can be kept serviced throughout the year. Store shelves should not be loaded with more honey than can be sold in a reasonable length of time. Containers should be kept fresh and clean, and the producer should see that the honey is prominently displayed. Honey that has granulated, particularly if in glass containers, should be replaced with liquid honey at regular intervals.

Current price levels should always be maintained. Cutting prices below current market levels results in a drop in the price of honey in a general area and may become a threat to the entire honey market. Such practice further presents an unorganized and unsteady market to buyers of honey, and often results in their ceasing to buy until conditions be-

come more stable. The price cutter also will find that his sales outlets will expect him to continue to reduce prices below future current levels. Honey always should be sold on its good qualities—not on a reduced price.

The ability to talk intelligently about honey is the first requisite of a good honey salesman. He should be well versed in the virtues and the nature of his product. He should understand floral sources and honey flavors and odors, the physical and chemical characteristics, honey grades, and especially pertinent food facts and uses of honey. Occasionally, the story of the life of the honey bee, the organization of the colony, and how bees gather nectar and make honey will contribute to his efforts.

Those who are successful in local marketing of honey are able to use methods of selling that are not possible for the large distributor to employ. There are abundant opportunities to talk about bees, honey, and honey products to schools, clubs, and other groups; to exhibit bees and their products on special occasions; to provide window displays and to advertise locally; and to increase sales in many other ways. They are in a position to give personal service to their sales outlets at regular and frequent intervals.

County and state fairs give the producer an excellent opportunity to exhibit honey and to create consumer demand. The honey must be of the highest quality, absolutely clean and clear, carefully packed in clean and attractive containers, and exhibited artfully. Beeswax of exceptionally good quality is often molded or carved into various interesting objects that add to the display. The honey and beeswax exhibits must meet the rules and requirements of the fair, and will be judged according to a grading system established by competent judges. Much interest can be created by live bees in observation hives, or in wire cages for demonstration purposes. Such apicultural exhibits have a decidedly educational influence on the public and develop many sales opportunities (Fig. 210).

If the beekeeper is located along a public highway, he may be able to dispose of his entire crop through roadside selling. The roadside stand has become quite popular and people are accustomed to buying foods of various kinds in this manner. Some sell other products besides honey, such as honey ice cream, honey candies, beeswax candles, wax figures, fruits, vegetables, eggs, and other farm and garden products. The roadside stand should be clean, attractive, well lighted, and roomy. Its location should be well marked by roadside signs. An observation hive or several colonies of bees will add much to the interest of those who stop to buy.

Selling helps and information about honey and its uses in cooking and baking can be obtained from the American Honey Institute, Madison, Wisconsin; from the Bee Culture Laboratory, Beltsville, Maryland; and from state sources and bee supply houses. Current price information contained in a semimonthly crop and market report, issued by the Agricultural Marketing Service, United States Department of Agriculture, Washington, D. C., is available to all beekeepers and is sent on request without

charge. The bee journals also contain current price and market information.

## Floral-Source Honeys

Often honey is sold as true to the floral source from which it comes. Some special honey shops have made a reputation by selling honeys of specific floral sources that suit the taste and choice of each customer. Honeys obtained in quantity from sage, orange, clovers, gallberry, tupelo, and other honey plants yielding choice light-colored honeys are ideally adaptable to this type of distribution. The blending of honeys may make other distinctly different colors and flavors of packaged honeys. Some have even added flavors that were distinctly foreign to natural honeys; such practice is not encouraged inasmuch as natural honeys comprise a wide variety of delightful and gratifying flavors and aromas.

## Co-operative Marketing

In recent years, co-operative marketing of honey has become a well-established industry. Earlier efforts to market honey co-operatively failed because of lack of information, faulty procedure, and failure to perfect efficient organizations. The future will see more co-operative groups or-


FIGURE 210. Honey—the gift of the flowers through nectar gathered by the bees—displayed in excellent manner at a state fair.

ganized effectively and soundly, and performing an excellent task of processing, packaging, and merchandising honey. The establishment of these co-operative groups will greatly aid our marketing problem.

At the present time, co-operative marketing associations are mainly of interest to large beekeepers who make a full-time occupation of the management of bees for the production of honey. These honey producers sign agreements to market collectively and share alike in profits and losses. The honey is usually collected at a central plant, stored, processed, packaged, and distributed under the direction of a paid manager and a sufficient organization for the conduct of business.

## Honey for the Baker

The American baking industry could profit from the experience of bread bakers in and near New York where the premium-priced loaf has been flourishing for more than a decade. Without exception, that bread is made with honey!

What is it that honey does for bread, cake, and other baked goods that makes them superior? Let us first consider bread. The premium-priced loaves of white and whole-wheat bread have a distinct flavor, texture, and color. The taste has a subtle difference that is delicious. The sugars of honey are in a simple form that enable the yeasts to go right to work, speeding up the process of fermentation and resulting in a fine uniform texture with no large holes. The crust has a characteristic chewy texture that adds to its appetizing appeal. The color of the bread is improved in that the crust takes on a deeper, richer brown tone. Honey bread keeps better, and one of the bakers' most annoying problems—drying out—is greatly lessened.

To get these fine qualities in bread, good honey must be used and in the proper quantity. Off-grade honey will not make bread of good flavor; neither is it necessary to use the very best quality, light-colored, delicately flavored honey. There are many kinds of honey available to the baker; there is no best variety any more than there is a best variety of apples. In general, light-colored and pleasingly flavored honeys, such as clover, alfalfa, orange, sage, and some of our light amber and amber varieties are desirable. Because honeys vary so much, bakers should be cautious and make initial purchases according to sample and then only from sources of unquestioned reliability. It is equally important that 6 pounds minimum of honey should be used to 100 pounds of flour, although to accentuate the flavor and to provide a touch of sweetness appropriate in honey bread 8 pounds of honey is better.

Bakers are vying with each other today to produce cakes that have all the richness of homemade cakes. In this connection, more and more honey is being used as bakers learn its value. In addition to improving the flavor, texture, and keeping qualities, honey seems to blend all of the

FIGURE 211. Delicious honey candy—made by Mrs. Lloyd R. Watson, Alfred, New York.

other flavors better, thus giving a much richer taste. Similarly honey finds use in the baking of cookies and special bakery products. In this instance, certain of our strong-flavored and darker honeys are highly desirable. One of the most important items using honey in the baking industry is the honey graham cracker which has become enormously popular with the consuming public throughout the land. Here again honey imparts a subtle flavor that the consumer likes.

The baking industry uses about 50 million pounds of honey each year, and so does its share to provide a good market for the producer, which in turn enables the beekeeper to keep honey bees flying and pollinating more than 50 of our food crops. Thus, the baking industry should be regarded as one of our best markets for good-quality honeys—not as a place where the producer can dispose of his poorest grades.

## Honey Products

*Honey butter* is a mixture of creamery butter and 20 to 30 per cent table-quality liquid honey. It has a fine, soft creamy texture and makes a tasty spread. After being prepared, honey butter cannot be kept for long without becoming rancid. A patented process for making a honey butter which does not become rancid is in use in New York State.

*Honey cream* is a mixture of fine-quality extracted honey, previously heated to melt all crystals and to destroy yeasts (to prevent fermentation) and enzymes (to avoid rancidity), mixed hot in the proportion of 42 per cent honey to 58 per cent high-test cream (75 to 80 per cent butter fat).

This product was developed by Professor Tracy,[5] of the University of Illinois. Honey cream is sometimes called "cream of honey" or "honey butter." Professor Tracy has also developed a chocolate-coated honey-cream bar that is delicious.

*Honey ice cream* is a delightful product. When honey is used to replace 50 to 100 per cent of the sugar in an ice-cream mix, a distinct flavor is given to the product and a new and pleasing variety is obtained.[6] Mild-flavored honeys, such as alfalfa and clover, are preferred to stronger flavors. Ice creams made with honey have a lower freezing point than those made with sugar and seem to be slightly smoother, but have a tendency to be crumbly and melt more rapidly at room temperature. Although the cost of the mix is slightly more than ice cream flavored with vanilla and sweetened with sugar, it is not as great as the average fruit mix.

*Honey candies* are delicious and wholesome (Fig. 211). There are candies of many flavors but none are more delectable than those in which honey is used. The hygroscopic property of honeys in certain instances enhances its use in candies, but in other cases detracts from its use. Additional information and recipes may be obtained from the American Honey Institute, Madison, Wisconsin.

*Honey vinegar* of excellent flavor can be made from unmarketable honey or from honey washings. The honey must be diluted with water until it contains about 15 per cent sugar.[7] Heating is usually necessary to dilute the honey. Inasmuch as heating destroys the yeasts and the acetic bacteria, and dilution reduces the required chemical elements, additions must be made. The following ingredients are suggested for one barrel of vinegar: extracted honey 40 to 45 pounds, water 30 gallons, ammonium phosphate 2 ounces, and potassium tartrate 2 ounces. Ordinary pressed yeast is suitable for starting alcoholic fermentation. For starting acetic fermentation, unpasteurized vinegar can be added.

---

[5]Tracy, P. H. 1932. How to make honey-cream. *Ill. Agr. Exp. Sta. Bull.* **387**.

[6]Tracy, P. H., H. A. Ruehe, and F. P. Sanmann. 1930. Use of honey in ice-cream manufacture. *Ill. Agr. Exp. Sta. Bull.* **345**.

[7]LeFevre, Edwin. 1924. Making vinegar in the home and on the farm. *U.S.D.A. Farmers' Bull.* **1424**.

# XVII. *The Honey Bee as a Pollinating Agent*

BY JAS. I. HAMBLETON*

THE fact that bees are important in the pollination of many species of plants is not new, but the fact that honey bees are becoming indispensable in our agricultural economy may be considered as relatively new.

Statements frequently have been made that the value of honey bees in pollination exceeds by ten to twenty times their value in the production of honey and beeswax. Often enthusiastic supporters of the honey bee like to give them full credit, say, for the production of an apple crop, on the basis that if honey bees were not available no fruit would set. However, we must consider that the production of a good crop of apples requires more than pollination; an orchard to bear well has to be properly pruned, soil fertility has to be maintained, plant diseases and insect pests have to be controlled, and the fruit has to be harvested and marketed—all of which goes into the production of a good crop.

The apple growers learned many years ago the value of honey bees in effecting a good set of fruit. It is now quite an accepted practice to move bees into orchards during the blossoming period for the purpose of insuring adequate cross-pollination. Apple pollen, like that of many plants, is sticky and heavy, and not transported by the wind. Since most commercial varieties of apples are self-sterile, the value of a reliable agent for transferring pollen from the blossoms of one variety to those of another is self evident.

In some of the fruit growing areas native or wild pollinating insects, such as the *Megachile, Nomia, Osmia, Andrenids, Bombus,* and other species, are so scarce in numbers that growers have resorted to hand pollination. While this is a highly satisfactory method from the standpoint of cross-pollinating the most compatible varieties and at the same time controlling the set of fruit, it is a laborious and expensive practice.

Other than the use of bees in orchard pollination, or to some extent the use of bees for pollinating cucumbers grown under glass, little effort

*James I. Hambleton. Chief of the Division of Bee Culture, U.S. Bureau of Entomology and Plant Quarantine, U.S. Department of Agriculture. Formerly instructor in entomology, University of Wisconsin. Since 1921, assistant in beekeeping and later principal apiculturist of the Bureau of Entomology and Plant Quarantine. Specialist in bee behavior and the role of the honey bee in pollination.

has been made to utilize honey bees in the production of seed or fruit. From the standpoint of the beekeeper, pollination has always been incidental. His primary object in keeping bees is to produce honey. Seed and fruit growers have left the matter of pollination mostly to chance. Little or no conscious effort has been made to control or do anything about this important function.

No one can question that we are rapidly approaching the time when honey production as the end product of keeping bees will be considered secondary. The accumulation of the effects of agricultural practices, together with possible future trends in the development of our agriculture, leaves little room to doubt that honey bees will play an increasingly important part in our agricultural economy (Fig. 212). This development seems destined to take place irrespective of what happens to the production of honey. The professional beekeeper in the future will be an expert in the use of bees in pollination. The production of honey to him will be a means of maintaining his colonies for use as pollinating agents.

## Effects of Agricultural Practices on Pollinating Insects

As has been mentioned in an earlier chapter, our common honey bee is not a native of the United States. It may be considered, therefore, our newest pollinating insect. It is not possible to discuss the role of the honey bee in our agricultural economy without mentioning native pollinating insects, inasmuch as modern agricultural practices have had such a devastating effect on these insects.

There was a time when no one was greatly concerned about pollination. Forty-five to 50 years ago it was not uncommon for red clover or alfalfa, under favorable conditions, to produce 8 to 10 bushel of seed per acre. Native pollinators were plentiful and it was taken for granted that if a crop flowered well, and other conditions were favorable, a good set of seed would result. Such heavy production is now a rare exception.

### Effects of Cultivation

Most of the native pollinating insects build their nests in or near the ground. With the exception of the bumble bee, all are solitary bees, building their nests in close proximity to one another. In an area of a few square yards, hundreds of nests may exist. The role of these bees in seed and fruit production has never been fully appreciated. No effort has been made to conserve these valuable insects. Nothing has been allowed to stand in the way of the plow. Any disturbance of the soil, either by plow or cultivator, destroys their nests.

Fence rows, particularly rail fences, provided generous, undisturbed stretches of land between fields—land which was not touched by the plow and which served as a safe harbor for many species of pollinating insects. Rail fences have been displaced by wire fences, which leave little or no

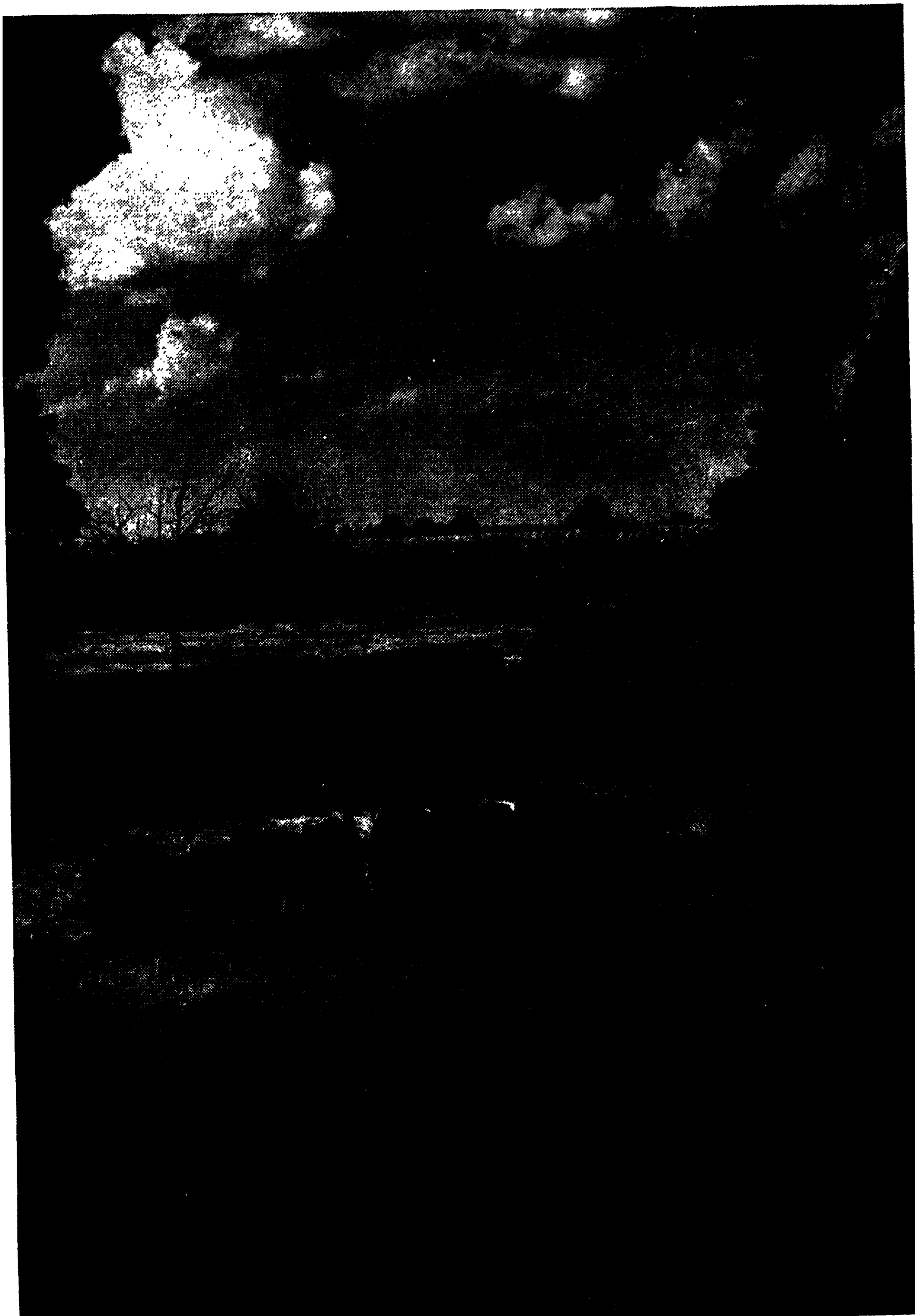


FIGURE 212. A balanced plan of agriculture—clover pastures, food for livestock, and consequently food for a nation—is dependent upon honey bees because of their pollination services. (*Photo by J. C. Allen & Son*)

FIGURE 213. This field of alfalfa, being cut just as it starts to bloom, is representative of large acreages planted to a single crop which offer relatively little food for pollinating insects. (*Photo by J. C. Allen & Son*)

undisturbed land. Modern farming equipment makes it possible to plow and cultivate the soil within a few inches of a wire fence, and further, to carry out the idea of neatness and to control weeds in some areas, even such fence rows are annually burned. Species such as the *Megachile*, which build their nests in hollow stems above the ground, fall an easy prey to this practice of brush and fence burning.

Clean cultivation of almost any sort is contrary to the welfare of many ground-nesting bees. Not too many years ago, it was the practice to have sod mulches in the orchards; the ground was undisturbed. Clean cultivation is now the rule.

Any radical change to the topography of the ground, such as irrigation, alters, usually for the worse, the habitat of the native insects; even their food plants are destroyed.

Planting large acreages to single crops (Fig. 213) has had a bad effect upon native pollinating insects. Most of these insects require a varied flora in order to complete their life cycle successfully. They need a succession of flora throughout the season. With the exception of the bumble bee, which does store a small amount of honey and pollen, sufficient perhaps to tide a colony over during a few days of adverse weather, most species live from hand to mouth, as it were. Three hundred acres devoted to red

clover furnishes relatively no food for pollinating insects, except during the short blossoming period. The same can be said for most of our agricultural crops. Our most extensively grown crops, such as wheat, rye, and oats, are practically useless as food plants for bees of any kind.

### Effects of Insecticides*

The use of insecticides for controlling injurious insects got well under way at the close of World War I. Up to the close of World War II, arsenic was the toxic principle in most commercial insecticides. Apple growers have depended almost entirely upon the arsenicals to combat the codling moth, an insect which has proved increasingly difficult to control. At one time, one or two sprays, properly applied, were sufficient, but in later years in some areas as many as thirteen or more cover sprays with arsenicals were necessary to produce marketable fruit. Spraying could not be confined only to the blossoming period but had to be continued until harvest. Arsenic has also been the basis, during all these years, for the control of most insect pests of cotton. Control of many vegetable insects, too, was dependent upon the use of arsenicals.

It is hardly conceivable that an insecticide effective in the control of injurious insects could be applied without bad effect upon beneficial insects. This is particularly true when insecticides are applied to open blossoms. It has long been recognized that the use of arsenicals was detrimental to beekeeping. In some areas thousands of colonies have been poisoned outright, not to mention the loss of field bees in colonies that were able to survive. Heavy losses of bees have occurred even though a honey-bee colony was fairly well protected against the effects of poison. Field bees which receive a toxic dose of poison usually die before entering the hive. Thus a colony may still survive after losing much of its field force. Where poison is carried into the hive, when mixed with pollen, the field force may not be greatly affected but the loss of brood through poison may produce in the end the same effect; namely, a weakening or destruction of the colony. The queen and the house bees are subject only to indirect poisoning since they do not fly in the sense that field bees do.

With the native pollinating insects, the counterpart of the queen honey bee has to fly to obtain food, not only for herself, but to provision her nest. No reliable figures are available as to how the use of insecticides has affected our native pollinators. The drastic reduction in the per acre production of seed of some of our legumes furnishes a clue to what the use of insecticides and other agricultural practices are doing to our useful insects.

The close of World War II apparently marked the dethroning of the arsenicals as our most dependable class of insecticides, the use of which has added to the woes and costs of beekeeping. Scientists are now develop-

*For additional information concerning insecticides poisonous to bees, see Chapter XXII, "Injury to Bees by Poisoning."

ing many new and more powerful insecticides, of which DDT is the forerunner. While DDT is toxic to honey bees when they come in contact with it or when it is fed to them in cages, its application in the field at first did not appear to affect them in so drastic a manner as the arsenicals.

The great killing power of the new insecticides and their cheapness of manufacture and application is revolutionizing insect control. Enough research has already been conducted to establish their efficiency. In a few years hence we may well look back upon this period as the insecticide era. Without doubt, the arsenicals as agricultural poisons are on the wane.

As long as the arsenicals were the main stock in trade for controlling injurious insects, it was not considered economical to apply them to such crops as corn, forage crops, and pastures. The new insecticides, however, can be applied cheaply and easily. We are already witnessing their use on alfalfa, corn, and other crops that have never been so treated before, and on forest areas. Millions of acres never before touched with insecticides will be sprayed or dusted by airplanes and ground machinery. If insecticides could be kept out of the blossoms, beekeeping should not suffer greatly. Human nature being what it is, it is too much to hope that insecticides will always be applied correctly. The outlook is indeed cloudy.

### Probable Effects of Herbicides

Herbicides, while in their relative infancy, give promise of being used in large quantities. Their application is not expensive and they are effective in destroying many kinds of weeds. Only preliminary tests have been made on their toxicity to bees. The early indications are that they are not toxic to adult bees in the dilutions recommended for their use as herbicides. Nothing is known as to the effect on brood rearing or egg laying if colonies were to obtain any substantial quantities. The danger to beekeeping and to the native pollinating insects in the use of these materials comes, however, in depriving insects of many species of food plants.

One of the first of the new organic herbicides to be put on the market, 2,4-D, is very effective in destroying dandelions. Many species of wild bees get their start in the spring by feeding on dandelion blossoms. As every beekeeper knows, dandelions constitute one of the best sources of pollen and nectar early in spring when colonies need every boost they can get. In the eyes of the beekeeper there is no substitute for this important plant.

The extensive use of herbicides, which would clear railroad right of ways and roadsides of dandelions, sweet clover, and other plants which furnish nectar and pollen, would handicap beekeeping and add to the complexity of solving the pollination problem.

### Summary

To recapitulate, the plow and the cultivator will continue in use. The development of more efficient farm machinery will encourage planting

large acreages to single crops. Rail fences will never come back; clean fence rows will continue in vogue. Injurious insects will continue their struggle to outwit man. More and better insecticides will be used to save our crops. What chances do the wild bees have? The only ray of hope is that conservation practices may encourage re-establishing some of the native pollinating insects. As of the moment, and certainly for many years to come, pollination will depend almost exclusively upon the honey bee. The conclusion is an irrefutable one. This country must have a thriving beekeeping industry. Every encouragement to the keeping of honey bees and wise and careful planning will be necessary to provide insect pollination.

## Crops That Require or Benefit by Insect Pollinators

It is not possible in limited space to enumerate all the crops or species of plants that require insects to effect pollination, or to name those plants which, while not completely dependent on insects, benefit nevertheless when the blossoms are freely visited by them. In fact, the insect-plant relationships of many species are still to be determined. An attempt will be made to list only some of the most important plants with which this subject is concerned.

### The Clovers

The small legumes, perhaps more than any other group of plants, are completely dependent upon bee activity for seed production. The clovers, and this includes red, white, alsike, ladino, and sweet, are mostly self-sterile. The flowers will not produce seed with their own pollen; therefore, cross-pollination is essential to good seed production. White, alsike, ladino, and sweet clover are freely visited by honey bees for both nectar and pollen, and bees can do an exceptionally good job in the cross-pollination of these plants. With red clover, the corollas are usually too deep for the honey bee to obtain much nectar. Thus, red clover honey is an exception. It is commonly thought that honey bees are ineffective in pollinating red clover—that only the bumble bee, with its long proboscis, can do an adequate job on this plant. Honey bees, however, under certain conditions visit red clover for pollen, and sometimes for nectar, and in doing so, do an excellent job of cross-pollination.

A conservative, theoretical maximum production of red clover seed is about 1500 pounds per acre. To attain such production would require the pollination of all corollas which in an acre of red clover would approximate 500 million. Naturally, conditions for the best growth of the plant and for the ripening of the seed would be necessary to attain such a high yield. The average production for the country, however, is less than 60 pounds per acre. Yet red clover grows just as well as it did when 8 to 10 bushel of seed per acre were not uncommon.

Red clover is a plant which adds fertility to the soil and fits in well with crop rotation. To be of maximum use to the farmer it should produce not only a hay crop, but also a profitable seed crop. Because of the low yield of seed in many areas, farmers are looking for a substitute crop.

### ALFALFA

The pollination of alfalfa presents a more difficult problem. The reproductive organs of this plant are locked in the keel of the blossom and remain hidden and unexposed to insects until the keel is opened or "tripped." While a minor amount of tripping may be effected through natural or mechanical means, such as agitation of the blossoms and high temperatures, most of the blossoms become abortive if not tripped and pollinated by insects.

A number of species of wild bees, particularly *Nomia* and *Megachile,* are effective trippers of alfalfa. When tripping takes place, usually cross-pollination is effected at the same time. With its own pollen the flower of alfalfa may mature from zero to only one or two ovules; cross-pollination may result in the development of 8 to 10 ovules. Even if there were some way to encourage selfing (seed formation without cross-pollination), the plants resulting from such seed are not so vigorous as those from cross-pollinated plants.

Honey bees are not the most effective trippers of alfalfa. If bees have easy access to other sources of pollen they do relatively little tripping, even though they may work the blossoms freely for nectar. There is evidence, however, that nectar gatherers do appreciable tripping. Since honey bees usually outnumber all other species of bees combined working on alfalfa, nectar gatherers should not be regarded as being of no importance in producing a good set of seed.

As an indication of the present shortage of legume seed production, in 1925, Utah produced 26 million pounds of alfalfa seed. Since that time there has been a steady decline, and the current production in that State is about 4 million pounds. Part of this decrease is due to the discouraging results obtained by seed producers who have consequently reduced the acreage left for seed. Agronomists are now frank in stating that seed production in alfalfa will not be materially increased until problems attendant upon insect pollination are solved.

### OTHER INSECT-BENEFITED CROPS

It is commonly supposed that plants which set seed or fruit by their own pollen do not require insect pollen carriers. For example, most varieties of sour cherries fall in this class, yet cherry growers are learning that more and better fruit is produced when bees are placed in the orchards during the blooming period. Under certain weather conditions, the transfer of pollen from the anthers to the pistil may not be adequate when left entirely to the action of the elements. Plants in which self-

pollination occurs, or in which pollination is brought about by the wind, cannot thus categorically be excluded as not being benefited to some extent by insect visitation. Many plants or blossoms which are self-compatible, that is, do not require cross-pollination, nevertheless produce better seed or fruit when crossing does take place.

As a matter of ready reference, there are listed below some of the most important of the insect-benefited crops grown in the United States.*

FRUIT CROPS

| | | |
|---|---|---|
| Almond | Cucumber | Peach |
| Apple | Dewberry | Pear |
| Apricot | Gooseberry | Persimmon, native |
| Avocado | Grape | Plum and prune |
| Blackberry | Huckleberry | Raspberry |
| Blueberry | Mango | Strawberry |
| Cherry | Muskmelon | Tung |
| Cranberry | Nectarine | Watermelon |

SEED CROPS

| | | | |
|---|---|---|---|
| Alfalfa | Alsike clover | Cucumber | Radish |
| Asparagus | Crimson clover | Flax | Rape |
| Broccoli | Ladino clover | Kale | Rutabaga |
| Brussels sprouts | Red clover | Kohlrabi | Squash |
| Buckwheat | Strawberry clover | Muskmelon | Sunflower |
| Cabbage | Sweet clover | Onion | Trefoil |
| Carrot | White clover | Parsnip | Turnip |
| Cauliflower | Collards | Pepper | Vetches |
| Celery | Cotton | Pumpkin | Watermelon |

There could be added to the list many noncultivated plants, including forest trees—plants of importance in conserving soil and moisture.

## Plant Factors Affecting Visitation of Bees

Placing an apiary within easy flight range of a crop that requires insect pollination does not guarantee that the crop in question will be benefited. Numerous experiments can be cited in which apiaries have been set down in the middle of alfalfa fields without any noticeable increase in the production of seed. When no thought was given to the character or proximity of competitive plants, it is not strange that the conclusion has been that honey bees are ineffective in tripping and cross-pollinating alfalfa. As a general rule honey bees have no great reputation as influencing the production of red clover seed. Many ill-advised and hasty conclusions have been drawn from uncontrolled experiments—experiments where the observers have not been sufficiently versed in the behavior of honey bees to arrive at the real facts.

*For further information concerning the importance of honey bees to many agricultural crops, *see:* 1942. The dependence of agriculture on the beekeeping industry. *U.S.D.A. Circ.* E-584.

## Effects of Sugar Concentration of Nectar

Vansell[1] and other workers have determined that honey bees will concentrate on the richest source of nectar and that not until the primary source is exhausted will the bees seek poorer sources, in which the nectars are of lower sugar concentration. As an indication of the variation in sugar content of nectars, the following data, taken from Vansell, are listed on the following page in tabular form.

In areas of diversified agriculture, in contrast to areas where cotton or some other plant is grown almost exclusively, bees often have access to a wide choice of forage. Where alfalfa and sweet clover are grown in proximity to each other, the sweet clover invariably proves the more attractive to bees to the detriment of the alfalfa. Under such circumstances it would not be strange to expect a low yield of alfalfa seed. Not only would the sweet clover draw the honey bees but it would also attract the wild bees. This would become particularly apparent where pollinating insects were scarce in proportion to the number of flowers available to them. Sweet clover represents a complete plant for most bees, as it furnishes both nectar and pollen, each being readily available to bee visitors.

## Competition Among Plants

Competition among plants and crops for bee visitors has been given little serious study. Agriculture has been conducted in this country without regard to planning or planting with respect to this competitive factor, or without respect to the proximity or abundance of pollinating insects. Indeed, it is only within the last few years that farmers and seed growers have paid any attention to the requirement for beneficial insects in producing seed crops. Meticulous care has been given to the preparation of the seed bed, fertility and moisture content of the soil, insect control measures, and other practices that go into the care and harvesting of a crop. But the essential factor of pollination has been allowed to take care of itself. The time is upon us now, however, when pollination can no longer be left to chance.

The effect of competition is readily apparent in some years, although the competitive factor has rarely been given credit for the production of a good seed crop. Alfalfa is an exceedingly deep-rooted plant and in dry years, although its growth may be stunted, the plant may still blossom and fruit abundantly. Shallow-rooted plants, which in years of normal or abundant rainfall blossom profusely and act as serious competitors, draw bees from the alfalfa. In dry years the shallow-rooted plants suffer, leaving alfalfa without a competitor for all the bees in the vicinity. As a result many growers of alfalfa seed believe that the arid condition of the plant is alone responsible for a good seed harvest.

[1]Vansell, Geo. H. 1942. Factors affecting the usefulness of honeybees in pollination. *U.S.D.A. Circ.* 650.

SUGAR CONCENTRATION OF THE NECTARS OF SOME CALIFORNIA AND OREGON PLANTS

(Arranged in order of decreasing sugar)

| Plant | Average sugar concentration |
|---|---|
| | *Per cent* |
| Alfileria (*Erodium cicutarium* (L.) L'Her.) | 65.0 |
| Black locust (*Robinia pseudoacacia* L.) | 63.2 |
| Willows (*Salix* spp.) | 60.0 |
| Locoweed (*Astragalus pachypus* Greene) | 59.2 |
| Wild buckwheat (*Eriogonum fasciculatum* Benth.) | 58.1 |
| Common vetch (*Vicia sativa* L., extra-floral nectar) | 56.5 |
| Sainfoin (*Onobrychis viciaefolia* Scop.) | 55.4 |
| Bachelor's-button (*Centaurea cyanus* L.) | 52.5 |
| Melanops vetch (*Vicia melanops* Sibth. and Sm., extrafloral nectar) | 52.1 |
| Bigleaf maple (*Acer macrophyllum* Pursh) | 52.0 |
| Deerweed (*Lotus scoparius* (Nutt.) Ottley) | 52.0 |
| Yellow sweetclover (*Melilotus officinalis* (L.) Lam.) | 51.6 |
| Dandelion (*Taraxacum palustre* var. *vulgare* (Lam.) Fernald) | 51.2 |
| Rape (*Brassica napus* L.) | 50.5 |
| Wild buckwheat (*Eriogonum* sp., annual pink, from eastern Oregon) | 50.5 |
| Salal (*Gaultheria shallon* Pursh) | 50.5 |
| Chickweed (*Stellaria media* (L.) Cyr.) | 50.0 |
| Common mustard (*Brassica campestris* L.) | 50.0 |
| Sweet cherry (*Prunus avium* L.) | [1] 50–60 |
| Flax (*Linum usitatissimum* L.) | 49.5 |
| Cultivated buckwheat (*Fagopyrum esculentum* Moench) | 49.0 |
| Horsechestnut (*Aesculus hippocastanum* L.) | 49.0 |
| Hoarhound (*Marrubium vulgare* L.) | 48.3 |
| White sage (*Salvia apiana* Jeps.) | 48.0 |
| Castor-bean (*Ricinus communis* L., extrafloral nectar) | 47.8 |
| Hungarian vetch(*Vicia pannonica* Crantz, extrafloral nectar) | 47.7 |
| Crimson clover (*Trifolium incarnatum* L.) | 47.7 |
| Cantaloup (*Cucumis melo* L.) | 46.7 |
| Perennial sunflower (*Wyethia angustifolia* (D. C.) Nutt., Oregon) | 45.8 |
| Jackass clover (*Wislizenia refracta* Engelm.) | 45.3 |
| Oregon grape (*Berberis aquifolium* Pursh) | 45.0 |
| Apple (*Malus pumila* Mill.) | 45–55 |
| Black sage (*Salvia mellifera* Greene) | 44.9 |
| Toyon (*Photinia arbutifolia* Lindl.) | 44.8 |
| Jim Hill mustard (*Sisymbrium altissimum* L.) | 44.1 |
| Hairy vetch (*Vicia villosa* Roth) | 44.0 |
| Alsike clover (*Trifolium hybridum* L.) | 43.3 |
| Locoweed (*Astragalus hornii* Gray) | 42.4 |
| Vine Maple (*Acer circinatum* Pursh) | 42.0 |
| Cotton (*Gossypium hirsutum* L., Acala variety, extrafloral nectar) | 41.9 |
| Buckeye (*Aesculus californica* Nutt., wide range, 33.0–50.8[2]) | 41.5 |
| Alfalfa (*Medicago sativa* L., except Imperial Valley data) | 41.1 |
| White clover, ordinary and ladino (*Trifolium repens* L.) | 41.0 |
| Spikeweed (*Hemizonia pungens* (Hook. and Arn.) T. and G.) | 39.9 |
| Privet (*Ligustrum* sp.) | 39.2 |
| Tamarisk (*Tamarix* sp.) | 38.8 |
| Wireweed wild buckwheat (*Eriogonum* sp., California) | 37.8 |
| Yellow star-thistle (*Centaurea solstitialis* L.) | 37.5 |
| Penstemon (*Penstemon* sp.) | 37.3 |
| Wild buckwheat (*Eriogonum* sp., yellow perennial | 37.3 |
| Milkweed (*Asclepias speciosa* Torr.) | 37.2 |
| Incense-cedar (*Libocedrus decurrens* Torr., honeydew) | 36.3 |
| Aster (*Aster spinosus* Benth.) | 36.2 |
| White sweetclover (*Melilotus alba* Desr., except Imperial Valley data) | 35.8 |
| Evergreen blackberry (*Rubus laciniatus* Willd.) | 35.6 |
| Fireweed (*Epilobium angustifolium* L.), wide variations with varying humidity | 35.0 |
| Canada thistle (*Cirsium arvense* (L.) Scop.) | 35.0 |
| Red clover (*Trifolium pratense* L.) | 34.3 |
| Linden (*Tilia* spp.) | 33.6 |
| Locoweed (*Astragalus watsoni* Sheld.) | 33.3 |
| Strawberry clover (*Trifolium fragiferum* L.) | 33.3 |
| Fenugreek (*Trigonella foenum-graecum* L.) | 32.9 |
| Creeping sage (*Salvia sonomensis* Greene) | 32.4 |
| Monkeyflower (*Mimulus* sp.) | 32.0 |
| Sunflower (*Helianthus annuus* L.) | 31.6 |
| Red gum (*Eucalyptus camaldulensis* Dehn.) | 30.0 |
| Peach and nectarine (*Prunus persica* (L.) Batsch. and *P. persica* var. *nectarina* (Ait.) Maxim.) | 30.0 |
| Catnip (*Nepeta cataria* L.) | 28.7 |
| Snowberry (*Symphoricarpos albus* (L.) Blake) | 28.6 |
| Purple vetch (*Vicia atropurpurea* Desf.) | 28.0 |
| Himalaya-berry (*Rubus procerus* P. J. Muell) | 27.2 |
| Bluecurls (*Trichostema lanceolatum* Benth.) | 27.1 |
| Locoweed (*Astragalus trichopodus* (Nutt.) Gray) | 27.0 |
| Tree tobacco (*Nicotiana glauca* Graham) | 25.9 |
| Hungarian vetch (*Vicia pannonica* Crantz, floral nectar) | 25.2 |
| Turkeymullein (*Eremocarpus setigerus* (Hook.) Benth.) | 25.0 |
| Navel and Valencia oranges (*Citrus sinensis* (L.) Osbeck) | 25.0 |
| Cotoneaster (*Cotoneaster harroviana* Wils.) | 24.5 |
| Wild vetch (*Vicia* sp.) | 23.1 |
| Common vetch (*Vicia sativa* L., floral nectar) | 22.6 |
| Melanops vetch (*Vicia melanops* Sibth. and Sm., floral nectar) | 22.6 |
| Rocky Mountain bee plant (*Cleome serrulata* Pursh) | 21.9 |
| Cotton (*Gossypium hirsutum* L., Acala variety, floral nectar) | 21.5 |
| Figwort (*Scrophularia californica* C. and S.) | 19.6 |
| Tulip poplar (*Liriodendron tulipifera* L.) | 19.6 |
| Flowering currant (*Ribes sanguineum* Pursh) | 18.9 |
| Blue gum (*Eucalyptus globulus* Labill.) | 17.0 |
| Locoweed (*Astragalus asymmetricus* Sheld.) | 16.0 |
| Manzanita (*Arctostaphylos* spp.) | 16–50 |
| Avocado (*Persea americana* Mill.) | 15.2 |
| Madrona (*Arbutus menziesii* Pursh) | 15.0 |
| Sour cherry (*Prunus cerasus* L.) | 15–40 |
| Eucalyptus (*Eucalyptus* sp.) | 13.4 |
| Yellow cleome (*Cleome lutea* Hook.) | 11.0 |
| Apricot (*Prunus armeniaca* L.) | 5–25 |
| Pear (*Pyrus communis* L.) | 4–30 |

[1]Two figures indicates a range between varieties or species.
[2]Ruth Beutler (*2*), in Germany, reported red buckeye with a sugar concentration of 66 per cent.

While considerable headway has been made in studying competition among plants for insect visitation as influenced by nectar secretion, little is known about competition with respect to the preference of bees for different pollens. Whether bees prefer pollen from one species to that of another is not known. One might presume, however, that if bees take the line of least resistance, as they often seem to do, they prefer to visit plants in which pollen is most abundant or most readily accessible to them. The factor of competition must always be taken into consideration in the planting of crops, and in the utilization of bees for effective pollination.

As an example, in fruit areas where mustard is grown as a cover crop, or where it grows abundantly as a weed, it may prove a direct competitor to apple blossoms for the visitation of bees. In both plants the sugar concentration of the nectar is about 55 per cent. In such a case, bees would be expected to split their working force on the two crops, to the possible detriment of a full set of apple. Since the nectar of pear blossoms rarely exceeds 15 per cent sugar, adequate pollination of pears would represent a more serious problem, as more competitors would be expected to interfere.

## The Use of Honey Bees in Pollination

Pending further experimentation there are not too many exact rules to apply to bring about the most effective use of honey bees in pollination. One good rule, however, which should apply in most cases is—the more bees the better. Another one might be the use of populous colonies heavy in brood rearing. A third rule might well be added; namely, place the bees as close as possible to the crop requiring pollination. There appear to be exceptions to some of these rules which will be discussed later.

### The Colony as a Pollinating Unit

For many years beekeeping and horticultural literature have suggested the use of one colony of honey bees per acre for apple or for other orchard fruits (Fig. 214). The same recommendation has often been made for the various clovers. One colony per acre may not be a sound or scientific recommendation but probably a good one, nevertheless, since in most instances some bees brought into an orchard are better than none. Several factors, however, need to be considered. A young orchard can be expected to have fewer blossoms than a mature one. An acre of red clover or alfalfa may contain several hundred times more blossoms than an acre of apple trees. An acre of bloom is highly variable, depending on the species of plants, their abundance, vigor, and other factors.

A colony of bees is also not a standard unit. When bees are needed for orchard pollination they have only recently come out of winter "quarters." Such a colony may not have more than 8,000 to 12,000 bees. This would apply particularly to colonies in single-story hives that had been poorly cared for. Colonies in two-story hives that have been fed pollen or pollen

FIGURE 214. Prune orchards in bloom in the Santa Clara Valley of California. Pollination by the honey bee or other insects is necessary for set of fruit. (*Photo by H. C. Tibbits*)

supplements, some weeks prior to orchard bloom, may well contain up to 35,000 bees. Colonies of the latter sort are heavy in brood rearing and demand large amounts of pollen to maintain themselves. There is more urge and need for the bees from such colonies to gather nectar and pollen than in the case of small colonies in which the queen has only recently started to extend the brood nest. The use of one colony of bees per acre consequently has little to recommend it.

Since orchard pollination is paid for on the basis of the number of colonies, it behooves the renter of bees to make certain that he is getting good populous colonies and not merely half-empty hives. Charges for the rental of bees usually run from $3 to $10 per colony for the blossoming period. Some beekeepers make a specialty of renting bees for pollination and have standardized their practice to the extent of furnishing only colonies having six or more frames of brood.

It has been the customary practice in orchard pollination to scatter colonies singly at the rate of one per acre throughout an orchard. Butler, Jeffree, and Kalmus[2] of the Rothamsted Experimental Station in England,

[2]Butler, C. G., E. P. Jeffree, and H. Kalmus. 1943. The behavior of a population of honeybees on an artificial and on a natural crop. *Jour. Exp. Biol.* 20(1):65–73.

FIGURE 215. A small group of colonies in an orchard at blooming time assures cross-pollination of the blossoms resulting in a good set of fruit of superior quality.

as a result of studying the habits of bees in their visitation to flowers, suggest instead of distributing the colonies singly that they be grouped (Fig. 215). Butler's work bears out that of Minderhoud,[3] of Wageningen, Holland, that the individual foraging bee confines its working area to a diameter of 4 to 5 yards. This work has been further verified under actual field conditions in England by Crane and Mather[4] while observing the work of honey bees in the pollination of white and red radish plants. Buzzard[5] in France earlier arrived at about the same conclusion as Minderhoud, although apparently he did not have access to Minderhoud's paper.

There is no reason to question the accuracy of the observations of these investigators. It is paramount that this basic behavior of the foraging bee be kept in mind in the use of bees for pollination.

Placing the hives in groups facilitates loading and unloading, and caring for the bees. Furthermore, the colonies will not be so much in the way of operations which may have to be conducted while they are in the orchard. It is conceivable that the same sort of grouping would be effective for the pollination of other crops that require cross-pollination.

[3]Minderhoud, A. 1931. Untersuchungen ueber das Betragen Honigbiene als Blütenstäuberin. *Gartenbauwissenschaft* 4:342–362.

[4]Crane, M. B. and K. Mather. 1943. The natural cross-pollination of crop plants with particular reference to the radish. *Ann. Appl. Biol.* 30:301–308.

[5]Buzzard, C. N. 1936. De l'organisation du travail chez les abeilles. *Bul. Soc. Apicult. Alpes-Marit.* 15:65–70.

### Behavior of Bees in Relation to Pollination

To elucidate further, when a foraging bee discovers a source of nectar it will continue to return to the same small area as long as nectar is available. Buzzard observed the same bees returning to the same plants for consecutive days. This fact was ascertained by marking individual bees and watching their behavior over a series of days. The areas of individual bees, of course, overlap; thus several bees may be found working simultaneously on the flowers within, say, a given square yard. The number of bees will be influenced by the richness of the nectar and by the abundance of bees in the immediate vicinity. A single bee in working on a large apple tree (Fig. 216), for example, might confine its activity to only a part of the tree. It would not need to fly from one tree to another in quest of nectar. Since most varieties of apple will not set fruit with their own pollen, such a bee would not be an effective cross-pollinator. This situation obtains when there are relatively few bees in proportion to the available flowers.

As the number of bees in proportion to the available blossoms is increased, competition is stepped up to the extent that all the bees may not be able to find working areas for themselves. The bees that cannot find areas that are not fully occupied by other foraging bees become what

FIGURE 216. A nectar gatherer sips nectar from the apple blossom. In so doing, pollen from the anthers of the blossom collect on her body, and is carried to other blossoms, accomplishing cross-pollination. (*U.S.D.A. photo by Knell*)

Butler[6] terms "wandering bees." These wandering bees consequently, to get any nectar, have to fly from the area of one bee to that of another, obtaining nectar wherever they may. Since such bees might well have to fly from tree to tree, the wandering bees constitute those most effective in cross-pollination. It follows that in using bees for cross-pollination it is desirable to produce a crowded condition so as to create as large a number of wandering bees as possible. Thus, Butler recommends that instead of locating colonies singly that they be placed in groups throughout an orchard to promote points of bee concentration, accordingly creating as many "wandering bees" as possible.

Buzzard earlier applied the term "vagabond bees" to the bees that lacked individual foraging areas. A better name for these bees would be in order. Wandering implies aimlessness; vagabond means carefree; and both words suggest laziness. The bees without fixed locations are definitely hard workers.

It could be, that under highly competitive conditions (many bees and few flowers), that the youngest bees to join the field force go through a competitive apprenticeship before acquiring areas of their own!

A plant breeder or a producer of pure seed of a crop in which insect pollination is desirable may wish to limit the number of bees so as to avoid the creation of wandering bees, thus reducing the chances for unwanted cross-pollination.

## Planting in Relation to Pollination

Planting to prevent undesirable cross-pollination between closely related species where pure seed is the objective is no doubt governed by a number of factors. Not much is known about the habits of wild bees in flower visiting. Many species are solitary. Bumble-bee colonies seldom exceed 300 individuals. There would not seem to be a need for "organization" in the field force of any of our wild bees. With respect to pollen collection most of the wild bees are less consistent than honey bees in confining their activities to a single variety. If the same holds for nectar the individual wild bee may be more useful than the honey bee in cross-pollination. Likewise, it may be more detrimental in bringing about undesired cross-pollination. Thus, it would be well to know something about the population of wild bees in an area where pure seed is produced. The population of honey bees in such an area should also be controlled. The abundance of both of these kinds of bees would be expected to influence the spacing of varieties to minimize cross-pollination. It is further conceivable that this spacing would vary in different localities. Staggering planting time to avoid simultaneous blossoming would seem to offer one solution to prevent cross-pollination.

---

[6]Butler, C. G. 1945. The influence of various physical and biological factors in the environment on honeybee activity. An examination of the relationship between activity and nectar concentration and abundance. *Jour. Exp. Biol.* 21(1 and 2):5–12.

## Orchard Pollination

When orchardists have difficulty in renting colonies within reasonable range of their orchards, special "orchard packages" can be purchased from producers of package bees. Such packages usually contain 5 pounds of bees, a feeder can, and are generally queenless. In placing them in the orchards such packages are given some protection by wrapping the cages in cardboard or some other appropriate material. Package bees work fairly satisfactorily and are superior to weak overwintered colonies, but are not considered nearly so effective as strong colonies. Rather, they represent an emergency measure for providing pollination.

The layman often considers that it is a boon to the beekeeper to allow him to move his colonies into an orchard; with millions of early blossoms the bees can supposedly reap a harvest and the beekeeper is all to the good. Fruit bloom is very welcome to the beekeeper, since it offers an early source of nectar and pollen for the build-up of colonies. It is doubtful, however, that colonies can ever be moved without some injury to them. Moving bees is also hard work; the colonies have to be screened and usually moved at night. Bees in an orchard, unless the application of insecticides is done with meticulous care, are subject to being poisoned. Often bees when taken out of an orchard are weaker than when they were moved there. Unless the monetary compensation is adequate, the orchardist gains more than the beekeeper by this practice.

Some orchardists are opposed to the use of honey bees for pollination. They claim that it causes too heavy a set of fruit, with a resulting costly thinning operation. In determining, therefore, the feasibility of renting bees, orchardists could well take into consideration the risk involved in not having bees, especially during the years when inclement weather reduces or limits the flight of all pollinating insects. According to Butler,* the bees that are working at the greatest distance from the hive are the first ones to curtail their flight in the event of bad weather. Those which have established their foraging areas close by will continue working longer under otherwise unfavorable conditions for flight. When pollinating insects are plentiful and close to the trees, a few hours of good flying weather might well make the difference between a profitable crop or no crop at all.

As has been mentioned previously, placing colonies of honey bees within flight range of a crop does not assure pollination. Bees might be rented for apple pollination, yet the trees in a near-by orchard may be in a more thrifty condition or in a more advanced stage and consequently draw part of the rented bees. In a case of this kind the answer would seem to be—use more bees. The excess of bees creates competition among them, forcing some of the bees to visit the less attractive plants. The same principle applies to other crops.

---

*See reference No. 6 in this chapter.

## Greenhouse Pollination

Honey bees are now used extensively for the pollination of cucumbers and other crops grown under glass (Figs. 217, 218). Nuclei, or small hives, consisting of three or four combs containing bees, brood, pollen, and honey are usually employed for this purpose. Nuclei, as a rule, do not fare well under greenhouse conditions; many adult bees are lost. Many bees fail to return to the hive and others fly out through the ventilators and do not return. Greenhouses seldom afford enough forage for bees and the highly artificial conditions under which they are kept result in their decline in strength unless the small colonies are given careful attention.

One would suppose that, if the nuclei contained only a small amount of pollen or none, the bees would be stimulated to work the flowers vigorously. Such appears not to be the case. Better results are obtained if these units are given combs containing plenty of pollen or provided with soybean-pollen cakes. The use of entrance feeders containing sugar sirup helps. The more the nucleus prospers the more vigorous the bees are in working the flowers.

FIGURE 217. Cucumbers! And such cucumbers! The result of pollination by bees under glass in the Davis Greenhouses, Terre Haute, Indiana. (*Photo courtesy Davis Greenhouses*)

FIGURE 218. Onions grown in a greenhouse, showing excellent set of seed obtained when bees were used for pollination. The clusters of seed head in center foreground are on male-sterile plants. In the background are the pollen parents. (*Photo courtesy Jas. I. Hambleton*)

The writer once visited a large commercial greenhouse in which several acres of cucumbers were grown under glass. The owners complained that the cloudy weather contributed to a high proportion of imperfect fruits. The visit happened to be at a time when the sky was overcast and the flight to the blossoms was of a desultory nature. An examination of the nuclei revealed the reason for this: practically no brood rearing was in progress and the bees were on the downgrade. Strong nuclei would have thrown out more field bees even during days when the sky was overcast; enough bees should have been present to "fight" over the blossoms. The cucumber flower has three stigmas and, to produce perfect fruit, all three must receive pollen to be pollinated. Greenhouse culture represents a concentrated and expensive type of agriculture. To economize on bees seems illogical, to say the least; the use of full colonies in many cases would be justified.

## TRAINING BEES FOR POLLINATION

Much interest is being shown in the possibility of training or inducing bees to work crops which they would not normally visit; crops which require insect pollination but are not attractive enough to entice the beneficial insects.

Frisch,[7] of Germany, unquestionably one of the greatest authorities on bee behavior, has studied the underlying principles which motivate bees in their search for nectar and pollen. His work certainly gives credence to the hope of utilizing bees for pollination more efficiently and positively than is possible now.

Reduced to simple terms, Frisch's experiments have been based on permeating the colony with the odor or fragrance of the flowers which it is desired that the bees visit. This is done by making a sugar sirup richer than that of competing nectar and steeping the blossoms in the sirup. This "baited" or flavored sirup is then fed to the colony in the evening, and the next morning, anxious to find this new rich source, the bees are said to visit the actual blossoms. It has been claimed that, by using this method, honey bees can be induced to visit plants that they ordinarily ignore completely. More detailed work and large-scale experimentation will be needed to apply this new line of thought to crop production.

### Pollination—A Community Problem

Even if an apiary is placed near a crop requiring pollination, the bees may or may not visit the crop in question. Unless the nectar is readily available or of high enough sugar content, or unless the pollen is easily obtained from that particular crop, the bees will go elsewhere. They may even visit a similar crop in another close-by locality. Native flora may draw the bees away from the crop for which they were intended. Since honey bees may fly from a mile to a mile and a half or farther from the apiary, it is necessary to take into consideration the character of the surrounding locality if the best results are to be obtained. In spite of all this, the grower who knows the value of bees can do no better than to have bees moved into his fields even though his neighbors' crops may be benefited more than his own. For this reason it is suggested that in certain localities the best solution may be for a community, having a large acreage of crops requiring insect pollination, to attack the problem co-operatively. In this manner the bees can be placed to the greatest advantage of all concerned and everyone served would help pay for the rental.

Not all areas support enough nectar- and pollen-producing flora to support beekeeping on a commercial scale (Fig. 219). Yet such areas might well be growing crops that require pollinating insects. There must be circumstances where it would pay growers to rent bees even if the beekeeper has to maintain them by feeding sirup and pollen for the sole purpose of keeping the bees in good condition for pollination.

To what extent could agriculture in submarginal areas be improved by honey bees? If nothing else, the soil-building legumes would have a better chance to become established. To get bees into such an area might well require community action. A commercial beekeeper could not pos-

[7]Frisch, K. von. 1943. Versuche über die Lenkung des Bienenfluges durch Dusstoffe. *Naturwissenschaft* 31(39–40):445–460.

FIGURE 219. The lady is emptying the tray of a pollen trap on a pile of pollen which contains 27 pounds of dried bee-gathered pollen. This amount is just a little over half that required by a strong colony during the course of a year. This represents, better than words can describe, the tremendous amount of work which bees do in maintaining themselves—also the great need for pollen-producing flora to support beekeeping on a commercial scale. (*Photo by Dr. H. A. Jones, Bureau of Plant Industry, Soils, and Agricultural Engineering, U.S.D.A.*)

sibly make a living until the legumes were established, yet bees might be needed the worst possible way. Pollination is never mentioned in the improvement of poor agricultural areas. Could this be one of the factors?

## When Honey Bees Are Not Wanted

Honey bees are not always an asset in pollination. Most blossoms wilt within a few hours after fertilization of the flowers has taken place. It is obvious, therefore, that pollination should be avoided for ornamental flowers except where it is essential in seed production. Honey bees are often detrimental to the growing of snapdragons for the cut-flower trade. Bees can be a particular nuisance in greenhouses when their services are not needed. No satisfactory repellent has been found to keep them out; the expensive screening of ventilators is the only way to exclude bees.

Bees are also objectionable in certain plant-breeding work where both selfing and crossing must be done according to a prescribed plan. Ladino and white clover, for example, cross readily. If pure seed is to result, these plants must be far enough apart to prevent the bees from carrying pollen from one to another.

### Transmitting Plant Diseases

Fire blight, azalea flower spot, and no doubt other plant diseases can be and are spread by honey bees. What applies to honey bees of course applies to wild bees as well. As far as is known, the honey bee is not the sole agent for disseminating any particular plant disease; it is usually only one of a large number of responsible agents. Often, however, the honey bee has been maligned as being the principal agent in the transmission of fire blight of apple, pear, and other orchard fruits. This has been proved to be not the case. Fire blight can be spread to trees that are devoid of blossoms—which are not even visited by pollinating insects. The honey bee is guilty no doubt of transmitting other diseases of plants, but its guilt has not been clearly proved.

If honey bees were primarily responsible for the transmission of a disease of plants in which insect pollination is essential, it would be difficult to imagine how their services could be dispensed with notwithstanding. The prime product of the beehive, honey, is a good sterilizer; the hive is not a fruitful place, therefore, for the harboring or overwintering of pathogenic organisms. It is significant that although man is the principal user of this product there is not a single case on record of attributing to honey bees the transmission of diseases of man or animals—that is, if we exclude the diseases of the honey bee itself.

### When Harvesting Fruits

Honey bees help in putting on a crop of fruit; they can likewise interfere with its removal or harvest. Mostly through ignorance honey bees

have been accused of ruining fruit, particularly grapes, at harvest time. Coincident with the fall harvest several of the social bees which abound in this country; namely, yellow jackets, hornets, and certain wasps, are more numerous than at any other time of the year. All these bees have mandibles or jaws provided with sharp teeth which can readily cut the skin of fruit. The worker honey bee lacks teeth of any kind and would starve to death if it had to depend on cutting ripe fruit as a means of acquiring food.

Since honey bees predominate in number, wherever fruit is concerned, at blossom period or harvest, they are often seen as the only guilty party. A lone wasp or hornet, or bird or beetle, may cut the skin of a ripe fruit, thus providing a source of sweet juice for a dozen honey bees. Fruit pickers see only the honey bees and, while they were not guilty in the first place, yet it must be admitted that their mere presence, so close at hand, is a hindrance to harvesting operations.

Overripened fruit that has been loosened at the stem or which has been bruised in any manner is attractive to honey bees. Pickers cannot be blamed for not wanting to compete with the bees.

Here again we are at a loss to write out a prescription to prevent this type of nuisance. Any chemical means of keeping the bees away might well affect the marketability of the fruit. Covering fruit will protect it, but this method is expensive if conducted on a large scale.

## Relationship Between Pollination and Honey Production

With relatively few exceptions, the beekeeper receives no compensation for the use of his bees in pollination. A few beekeepers in the Pacific Northwest, and perhaps elsewhere in limited numbers, are in the business of pollination. It is doubtful, however, if more than a few beekeepers make a livelihood from rental of bees. Persons who keep bees with the expectation of making a livelihood depend upon the production of honey; what they may receive for pollination is of minor consequence.

By and large, seed producers, melon and cucumber growers, many orchardists, and growers of small fruits do not yet understand to what extent their production is dependent on honey bees. Just how long it will take growers of such crops to realize what they owe to the bees remains to be seen. An extensive educational program is needed.

The subject is a complicated one. Exact data are required as to the value of bees in pollinating specific crops to arrive at a just procedure for compensating the beekeeper. Concessions and exceptions will have to be made. In a dry year when weeds and native flora are not attractive to bees, a cultivated crop, take for example cantaloupes grown under irrigation, may prove highly attractive to honey bees. From the standpoint of effective pollination, this combination is ideal. The melon grower, however, has to use insecticides on his vines. In this case the attractive blos-

soms would constitute a veritable "bait trap" for pollinating insects. Is the answer some sort of special nucleus or package which would be used solely for pollination without thought of salvaging the bees afterwards?

Due to the very nature of the beekeeping industry, it would appear that some other answer should be forthcoming. Inasmuch as beekeeping has a tremendous number of drawbacks, as outlined below, another basis for solving this problem which has so great a bearing on our agricultural economy is suggested later.

Bees are subject to contagious diseases of several kinds. They must have food every day in the year for a bee will starve to death in a day's time. Many of the commercial crops that require bees for pollination constitute only minor sources of nectar. At times of low honey prices and relatively high prices for labor, materials, and equipment, beekeepers automatically curtail their operations. While this may reflect in the output of honey, not too important for the country at large, reducing the number of colonies is bound to affect the production of all insect-pollinated crops.

The marketing of honey presents many difficulties. Honey is produced over a wide territory; its color ranges from water white, through the ambers, to an almost black honey; and its flavor varies from the very mild fireweed honey to the strong-flavored buckwheat. Food packers dote on highly standardized goods in which color, texture, and flavor will be the same year in and year out. The great variation in honey and the expense of getting together large enough quantities to maintain uniform blends has discouraged food packers from promoting the sale of honey.

Many producers market their own product locally; the beekeeping industry is not well organized. With its membership spread from coast to coast and border to border, effective organization is extremely difficult. This has resulted in instability in the honey market—a perennial worry to the commercial producer.

Those who use bees for pollination must realize that honey bees cannot be furnished free of charge. The value of bees in the production of fruit and seed crops is many times that of the honey crop. As long as the keeping of bees must remain in the hands of beekeepers, fruit and seed growers will suffer whenever the beekeeper has reverses. Inasmuch as the beekeeper's livelihood comes from honey production and as long as he is not paid for the pollination work of his bees, he cannot be held responsible for inadequate pollination.

The growing of cash crops, such as corn, wheat, oats, and soybeans, has deprived many beekeepers of forage. Honey production has been so reduced in some areas that beekeepers are moving away or going out of business. The loss of honey in such areas is not of great concern. But to deprive an area of millions of pollinating insects, however, is a momentous problem—one for political units to solve. Arrangements will have to be made to maintain honey bees in agricultural areas. This may necessitate resorting to subsidies until pollination can be placed on a businesslike basis.

# XVIII. *Sources of Nectar and Pollen*

BY FRANK C. PELLETT*

ONE of the problems most puzzling to the honey producer is the relationship of the available bee pasture to his apiary. The amount of surplus honey that can be harvested from his colonies depends upon the abundance and the extent of a few major honey plants which yield nectar freely within flight range of his apiary. Minor sources of nectar and pollen, which provide for the colonies outside the main honeyflow, are as important as the major sources from which the surplus crop is obtained. When both pollen and nectar are available in early spring, the bees build up rapidly, soon attaining storing strength. Likewise, with forage of similar value available in autumn, the bees enter winter with large clusters of young bees and with sufficient honey and pollen reserves to enable them to start brood rearing late in winter to insure spring prosperity. The available bee pasture determines the entire plan of beekeeping operations.

## Limitations of Pasture

Some locations offer a splendid major honeyflow but are so poor at other times that it is difficult to maintain a profitable enterprise. Other places provide ideal conditions for building colonies and maintaining them, yet they yield so little surplus that a profitable crop is rarely secured. Therefore, a location with only a moderate honeyflow but with good supporting flora may prove more profitable in the long run than one with a heavy major flow and with poor off-season support.

There are many places where not more than 20 or 30 colonies may be kept profitably in one spot, and the beekeeper will do well by having many small apiaries. On the other hand, in some regions of New York where buckwheat was raised generally at one time, it was possible to keep five hundred or more colonies in one yard. It seemed hardly possible during the height of the honeyflow to overstock these places, which also were situated in wooded areas with a wide variety of trees and plants which provided nectar and pollen for spring and fall.

*Frank C. Pellett. Field editor of the *American Bee Journal*. Formerly state apiarist of Iowa. Author of *Productive Beekeeping*, *History of American Beekeeping*, *A Living from Bees*, *American Honey Plants*, and many other books. In charge of the honey plant test garden established by the *American Bee Journal* at Atlantic, Iowa.

In the Plains region sweet clover often is grown in sufficient acreage to support large apiaries during the main honeyflow. If the beekeeper can find such a spot with enough off-season support, large numbers of colonies may be kept there all the year. However, there usually is not enough pollen for spring and fall in the average neighborhood in this area.

Locations with a light flow over a long period, as in many of the Southern States, are favorable for brood rearing, making possible the production of package bees and queens for sale to northern beekeepers operating where large areas of plants offer a heavy flow. For this reason there has occurred a division of occupation in the beekeeping industry whereby both the northern beekeeper and the southern producer are benefited.

In an attempt to harvest more than one crop in one season, migratory beekeeping developed. Previous to the automobile migration was difficult and unsatisfactory. Now beekeepers often find it possible to overcome the limitations of off-season support, or to obtain more than one crop, by migration. Moves of several hundred miles are not unusual. However, long moves are expensive and the beekeeper who makes them should be quite familiar with conditions at both ends of the line.

## Influence of Pasture on Management

The nature of the honeyflow, whether it is heavy or light, or of short or long duration, and the time and the season when it occurs, affects practice materially. The nature of the honeyflow also determines whether the production of bulk comb or section comb honey is desirable or whether it is better to produce extracted honey. To secure a well-finished section of honey a heavy, sustained flow is required. When the honeyflow is long and slow it is difficult to produce comb honey and too much of the crop will be of low grade.

The time of the flow also determines whether the beekeeper is able to make his own increase or whether it is advisable for him to buy bees elsewhere. There are places where the principal flow is in the late summer allowing ample time to make colony divisions and to bring them up to storing strength. On the other hand when the crop comes early in the season there is not enough time for this and much of the increase must be supplied from other sources.

There are places in Maryland and the adjacent territory where the flow from the tulip poplar comes so early that it is extremely difficult to get the colonies strong enough to gather a surplus, and often it is not possible to make much increase during the honeyflow. It takes expert management to produce honey profitably in such a place unless there are other substantial sources of nectar occurring later.

One who lives where bitter or unpalatable honey is gathered will find operations complicated by the need to remove such honey ahead of any flow from a marketable source. A very small amount of undesirable

honey will spoil a large quantity of good honey if mixed with it. Where possible, the undesirable honey should be set aside for food for the bees in winter and early spring, thus making full use of it.

A well-known source of bitter honey is the bitterweed (*Helenium tenuifolium*), common to roadsides and waste places from North Carolina to southern Missouri and south to Texas and Georgia. It blooms over a long period, adding to the difficulty of the beekeeper. The honey is extremely bitter and unpalatable when fresh. Apparently the bitterness is due to the pollen grains and the flavor becomes less objectionable when these have settled. When extracted and permitted to stand for a time, the honey loses some of the bitter taste although it is never a good honey.

Another dark and strong honey with a bitter taste comes from the chinquapin (*Castanea pumila*), a small tree found from New Jersey southward and westward to Georgia and Texas. It is reported most often from the Southeast, especially Georgia and adjacent territories. Like the honey from bitterweed it should be kept off the market and used for feeding.

The honey from privet (genus *Ligustrum*) is said to be nauseating, and bitter in taste. There is so little of it generally available in this country that we don't hear much about it, but from England come numerous reports of the spoilage of good honeys through mixture of nectar from privet. Likewise, ragwort or groundsel (genus *Senecio*) is said to result in a honey with a strong and almost bitter flavor.

It is likely that the presence of some plant in the neighborhood is responsible for lowering the grade of large quantities of honey. In many neighborhoods fall honey is a mixture of varying quality from a great many different flowers. And the plant with the smallest yield, if it happens to be of poor quality, may determine the grade of the entire output.

## Changing Bee Pastures

The changes occurring in agriculture each year are of major importance to the beekeeper because they often constitute a change in the available bee pasture. Commercial beekeepers, especially, are affected seriously because they have a substantial investment in honey houses and equipment.

For instance, in 1916, there was a heavy honeyflow from white Dutch clover in the Midwest. It was the main source of surplus upon which beekeepers had depended for a long time, but that year marked the close of the white Dutch clover era. There have been years since when good crops have been secured from it, but 1945 was the only year when a large crop from this source was harvested throughout the entire region.

A series of dry years in the 1930's discouraged farmers from growing red clover in many places. Gradually sweet clover was adopted in its place, although previously it had been slow to receive recognition. Better conditions were thus provided for the beekeeper and his dependence for

a honey crop was shifted from white Dutch clover to the increasing acreage of white sweet clover (*Melilotus alba*) and yellow sweet clover (*Melilotus officinalis*).

Often the major source of honey disappears and the beekeeper is forced to move. This happened on the eastern slope of the Rocky Mountains following the first World War when alfalfa was replaced by sugar beets. In Texas, clearing off the wild growth of catsclaw, huajillo, and mesquite destroyed famous bee pasture where formerly trainloads of honey were produced. The removal of gallberry in the South and the reduction of buckwheat in the East produced the same effect, and we now find small apiaries where once large numbers of colonies were kept. Looking back to about 1910, only a few of the places which then supported large apiaries are now important.

It is easy to conclude that under some situations, where only one source of surplus honey is available, it is often not advisable to make large investments in permanent fixtures, such as buildings and land. The beekeeper should be able to move readily when failure comes or he should locate where there are diversified sources and chances of failure are less. Dairy districts have been the most stable, as far as bee pasture goes, since the dairyman depends to a large extent on clovers for hay and pasture. Wherever dairying is an established industry, beekeeping should be rather permanent.

## Factors Controlling Nectar Secretion

Much remains to be learned about the factors that control the secretion of nectar. At times a given plant may yield nectar freely; at other times, when conditions appear to be similar, little or no nectar will be available. Soil, temperature, humidity, sunlight, and other environmental conditions contributing to the prosperity of the plant have their effect. In general we may assume that when conditions are most favorable to normal plant life nectar is secreted, although this may not always be true. Often a heavy yield of nectar occurs when conditions appear to be extremely unfavorable, as sometimes happens at the beginning of a severe drought. Careful observations will be required to determine all the factors concerning nectar secretion of important honey plants.

Competition between flowers of different plants, open at the same time for the attention of the bees is now the object of some study. It is assumed that the flowers with nectar having the greatest sugar concentration have the greatest attraction for the bees. It is often observed that bees will fly over pear trees in full bloom to visit other blossoms presumably because they contain nectar of higher sugar content. It also is known that, once attracted to an abundant source of nectar, bees will continue their visits to this source even though other nectaries with a higher sugar content may become available later.

The method, developed by Dr. O. W. Park,* of measuring the sugar concentration of the contents of the honey sacks of bees by means of the refractometer makes it possible to determine quickly and easily the sugar content of the nectar of plants upon which the bees are working. Indications are that the sugar content of the available nectar has an important bearing on the attraction of any particular plant for the bees.

### The Influence of Soil

Little honey is secured from any of the clovers except on limestone soils. On the other hand, honey from buckwheat usually is secured on soils acid in character. Buckwheat honey crops are heaviest on sandy or light soils in the Northeast where the temperatures are moderate and the humidity is relatively high. Sweet clover yields best in the Plains region on soils rich in lime and with relatively high temperatures and low humidity. Therefore, sweet clover and buckwheat appear to require directly opposite conditions. Cotton yields well on heavy black soil and poorly on light sandy soil. Although we do not know the soil requirements of all the major honey plants, it appears that for each one certain soils are necessary for maximum nectar yield.

### Temperature and Humidity

Temperature and humidity apparently play an important part in nectar secretion. Rolf Lunder[1] states that, in Norway, alsike clover does not yield when the temperature is below 73.4° F. and the yield is not good until the temperature reaches 83° to 85°. The statement is made that on the coast of Norway, where the summers are never actually hot, clover scarcely yields.

Sweet clover reaches its maximum yield in the central river valleys and northward through Canada where the summers are dry and the soil is only moderately moist. Where sweet clover does its best there is likely to be only a light flow from the other clovers. Apparently alsike and white Dutch clover require more humidity than sweet clover for both do better where there is greater humidity and more moisture.

Floyd and Mitchener[2] state with respect to Manitoba where sweet clover seems to be the most important honey plant: "The more hours of sunshine there were during the day, other factors being similar, the greater the gain in the hive. Hot days were especially good for nectar secretion, especially if they were preceded by cool nights." It has long been noted that warm days following cool nights are favorable for nectar secretion in some plants. These results indicate that the greater the spread between day and night temperatures, the larger the gains made by the colony.

---

**See:* Chapter IV, "Activities of Honey Bees," by Dr. O. W. Park. p. 142.

[1]1940. International Congress papers—II. *Bee World* 21:78–79.

[2]Floyd, L. T. and A. V. Mitchener. 1925. Beekeeping. *Manitoba (Canada) Agr. Coll. Ext. Bull.* 78.

Kenoyer[3] has shown that, with white Dutch clover in Iowa, "the fluctuation in yield for a producing period seems to be closely correlated with the temperature range and the barometric pressure acting jointly." He further showed that "a good nectar-yielding year has a rainfall slightly above the average, the honey season being preceded by an autumn, winter, and spring with more than average precipitation." The yield is best on days with a maximum temperature of 80° to 90° F.

Kenoyer[4] gives the results of a study of a 30-year weight record of a colony on scales kept by J. L. Strong, Clarinda, Iowa: "Thirty-eight periods of continual and fairly rapid gain in weight were selected, and the days of each divided about equally between days of high gain and days of low gain. In 32 cases, the average daytime temperature range for the days of high gain is greater than for the days of low gain. In all of the six exceptional cases, the difference between the average is small."

Kenoyer also relates the contentions of Bonnier and Flahault that nectar secretion is greater in the same species at high latitudes and altitudes than at low when the species grows normally in both latitudes of altitudes compared, and furthermore that species which do not secrete nectar in France do so in Norway and in the Alps. It has often been noted that white Dutch clover yields larger crops in Michigan and Indiana than it does in Louisiana where it is equally abundant.

Kenoyer was unable to find evidence of increased yield because of change in atmospheric pressure and concludes: "It is a matter of common knowledge among beekeepers that bees are more active when the barometer is low, the warmth and stillness of such periods favoring activity. Hence is seems probable that any relation between atmospheric pressure and honeyflow is to be attributed to the bees and not to plants."

In a study of the honeyflow from goldenrod, Oertel[5] concludes that the correlations between the average temperature, maximum temperature, and daily gross gains are so small that they cannot be considered to show any relationship between these factors and colony gains in Louisiana.

## Influence of Light

Darwin[6] noted the fact that extrafloral nectaries of vetch are stimulated by light and that other plants require the stimulation of light to insure nectar secretion. Kenoyer also experimented with both floral and extrafloral nectaries of *Impatiens sultani* and found that the withdrawal of light makes its influence rapidly and decidedly felt.

---

[3]Kenoyer, L. A. 1917. The weather and honey production. *Iowa Agr. Exp. Sta. Bull* 169. p. 26.

[4]Kenoyer, L. A. 1916. Environmental influences on nectar secretion. *Iowa Agr. Exp. Sta. Bull. 37*. p. 224.

[5]Oertel, E. 1932. Honeyflow from goldenrod in its relation to temperature at Donaldsonville, La. *Jour. Econ. Ent.* 25(3):520–524.

[6]Darwin, C. 1876. *Cross- and Self-Fertilization in the Vegetable Kingdom.* London. Murray. Chap. X.

It thus appears that the intensity of light in higher altitudes, as well as the long days in more northern latitudes, may account for the heavier honeyflow noted there. Since it is well known that the rapidity of plant growth is correlated with the hours of daylight, it may be that this factor is of greater importance in the secretion of nectar than has been recognized so far. It is possible that light may have influenced the higher yields Mitchener credited to higher temperatures due to longer hours of sunshine.

## Major Sources of Surplus Honey

While bees gather nectar from many different plants, the greater part of surplus honey comes from a relatively small number of plants present in abundance over wide areas.

### Sweet Clover

The story of sweet clover (Fig. 220) is unusual. It was brought to this country apparently by accident. It soon became known as the "bee plant" or "honey plant." For more than a century beekeepers sought to spread it as a pasture for their bees while farmers fought it as a noxious weed. It was not until after the first World War that it was given a place in farm rotations as a soil builder. The plant seemed to be at its best in the Midwest with its limestone soil, dry warm days, and relatively cool nights.

Figure 220. Sweet clover—source of the greatest quantity of honey produced in the United States. While gathering nectar from this most important source, the bees pollinate the flowers, resulting in the setting of seed necessary for the perpetuation of this important soil-building legume.

The nectar yields were often so heavy that great enthusiasm prevailed and expansion of honey production was rapid. Sweet clover soon spread over the north central river valleys and the northern Plains region.

Sweet clover is a midseason source. The honey is light in color, in many cases almost water white, and of mild and pleasing flavor. The total yield has been so large as to overshadow that from any other source. Because sweet clover often is cultivated in large acreage, there has been a tendency for large, commercial beekeeping outfits to seek sweet-clover locations, often at the expense of long moves. The annual forms, including Hubam, have found favor in some localities.

### ALFALFA

The greater part of alfalfa honey, unmixed with other sources, comes from the irrigated regions. Much of the crop produced in the valleys of the Rocky Mountains is from this source. Alfalfa *(Medicago sativa)* is at its best on limestone soil where there is ample moisture and warm, dry, sunny weather. Formerly it was thought that alfalfa would not yield in the Eastern States, but during the series of dry years of the 1930's good crops of honey from alfalfa were reported in many places, including Michigan and New York. It is doubtful whether it yields except in time of relatively low humidity.

Alfalfa honey varies greatly in quality, depending upon the locality in which it is produced. In the high valleys of the Intermountain region and in northern areas it is light in color and mild in flavor, while in low altitudes in Arizona and southern California the color is dark and the flavor is strong.

### WHITE DUTCH CLOVER

White clover (*Trifolium repens*) is a common pasture plant from the Missouri River east and, on suitable soils, as far south as Louisiana (Fig. 221). It yields much better in the northern part of its range, but it does produce surplus honey elsewhere. The plant is shallow-rooted and suffers seriously from drought. It tends to disappear from soils deficient in lime.

There has been a great decline in the production of honey from white Dutch clover in recent years. Whereas it was once an early summer source of large production, the output is now probably less than the honey from either sweet clover or alfalfa. White clover honey is of mild flavor and usually light amber color, although the color varies greatly according to the locality from which it comes.

### ALSIKE CLOVER

Alsike or Swedish clover (*Trifolium hybridum*) was brought to this country in 1839 and it appears that beekeepers were largely responsible for its rapid spread. Unlike sweet clover, it was adopted at once by farmers who appreciated its value. Alsike is grown largely in the dairy regions

FIGURE 221. White Dutch clover, the dean of pasture legumes, was once an early summer source of large quantities of delicious honey.

of Minnesota and Wisconsin, and to a less extent throughout the Northeastern States and eastern Canada. Because it will grow on soils too wet or with insufficient lime for red clover to prosper, it has served many who lacked a suitable legume (Fig. 222).

Alsike clover honey is similar to that from white Dutch clover and the two are often mixed, going to market together as clover honey.

### VETCH

The vetches (genus *Vicia*) are widely cultivated but are reported as important for honey principally from the North Pacific Coast. Although vetch is reported as a rather dependable source of honey from British Columbia to Oregon, large crops like those from the clovers are rare. Much of the nectar comes from extrafloral nectaries and usually the yield is light. The honey is of heavy body making it difficult to extract at times. The flavor is mild and the color is amber.

In recent years vetch has come into cultivation in many localities in the South from the Carolinas westward through northern Georgia, Tennessee, and adjacent regions to east Texas. There have been many reports of honey from vetch in this area and beekeepers are enthusiastic regarding the spread of the crop. The color of the honey from this region is reported as being much lighter than that produced in other localities

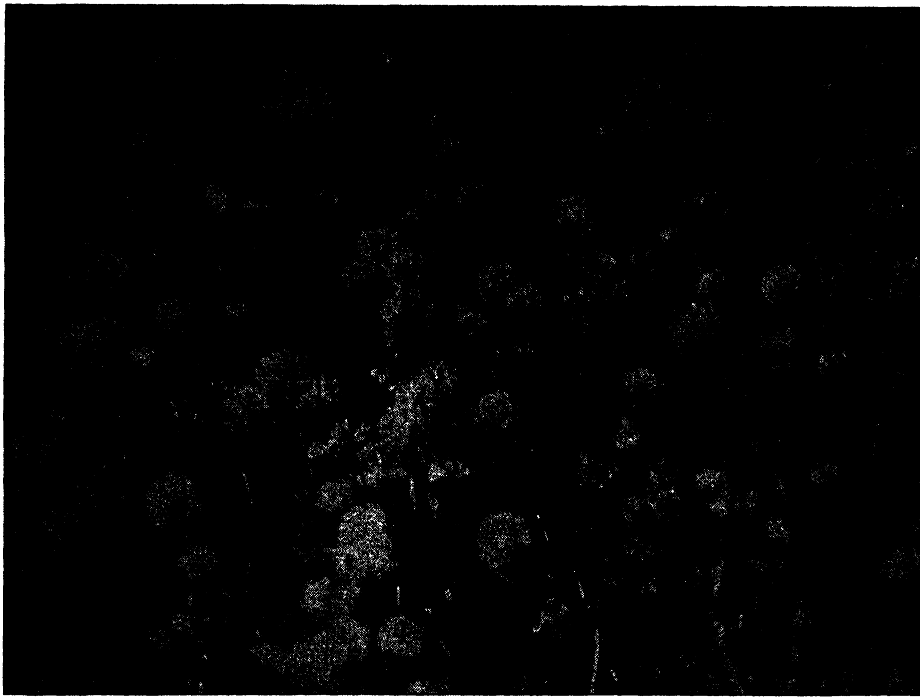


FIGURE 222. Alsike, or Swedish, clover is grown as a pasture and hay crop, and is an important source of honey in the Midwest.

### COTTON

While cotton (*Gossypium herbaceum*) is the major farm crop of the Southern States, it is important for honey in only a relatively small portion of its range (Fig. 223). It yields little nectar on sandy or other poor soils, yielding best on the black soils of Texas.

Cotton honey is light in color but varies greatly in quality. From some localities the flavor is regarded as indifferent while under other conditions the quality is high. When first gathered the honey is thin with a disagreeable taste which disappears when the honey is properly ripened. When harvested from thrifty plants on rich soils and fully ripened, cotton honey is usually of light color and good flavor. At times the cotton plants are covered with aphids and the bees may get honeydew from this source. This may be responsible for some of the reports of low-grade honey from cotton.

### BUCKWHEAT

Most of the buckwheat honey is produced in the region of the Great Lakes, in Ontario, New York, Michigan, and Pennsylvania. Buckwheat (*Fagopyrum esculentum*) does best on sandy or other light soils and seldom yields on clay or heavy soil. Buckwheat (Fig. 224) yields a very dark

FIGURE 223. Flower and mature green unopened boll of the cotton plant which provides clothing for people, but also provides a honey that is light in color and of good flavor. (*Photo courtesy Bureau of Plant Industry*)

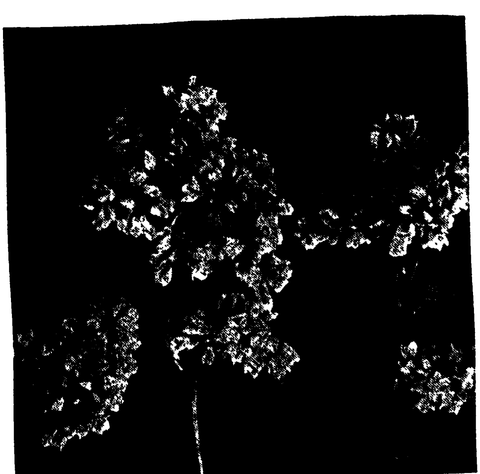


FIGURE 224. The flowers of buckwheat, reminding us of pancakes and a dark honey of pronounced flavor liked by many.

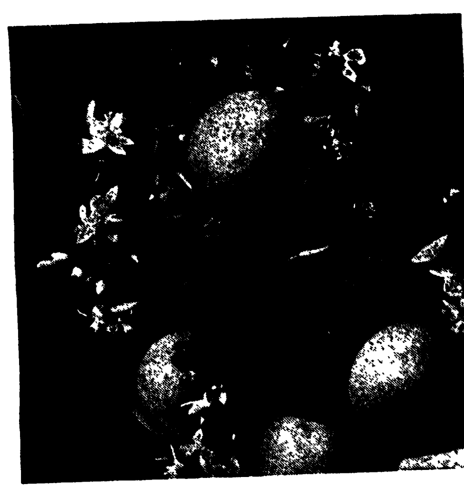


FIGURE 225. Oranges and orange blossoms —the latter being a lovely and delicate source of a mild-flavored honey.

honey of pronounced flavor which is popular with many. It is so different from the mild-flavored, light-colored honey from the clovers that they seldom appeal to the same people.

### Orange

Although the bees gather honey from a large variety of fruit blossoms, only the orange (*Citrus aurantium*) is a major source of honey (Fig. 225). While some honey comes from it in Florida, Texas, and Arizona, the bulk of orange honey is harvested in California where it is one of the principal sources of surplus. The flow may be very heavy and is likely to last about 3 weeks. Along the coast the fogs are unfavorable for the orange and the crop is uncertain, but in the valleys good crops are the rule. Orange honey is light in color and of marked but pleasing flavor, much in demand at a price somewhat above that of other California honeys.

## Wild Plants of Major Importance

In former years wild plants were of much greater importance as a major source of honey than they are now. This has gradually changed as the wild lands have been cleared, and cultivated crops have replaced the native flora. Much honey from wild sources still goes to market in some places, but the relative amount is constantly diminishing.

### Basswood

Honey from the basswood or linden (*Tilia americana*) is light in color but of pronounced flavor. Once one of the best-known honeys in the Chicago market, it has all but disappeared. The clearing of the forests from New England to Minnesota and southward has removed this beautiful native tree so that few beekeepers are able to get surplus from it.

Basswood is of special interest to the beekeeper since no other wood has served so well in making comb honey sections. It is still almost the only acceptable source of supply for this purpose.

### Wild Raspberry

The wild raspberry (genus *Rubus*) is a native from New England and eastern Canada to Oregon and Colorado and south to southern Ohio, and along the mountains to Georgia. Big crops of honey from this source came principally from northern Michigan where raspberry honey was famous. Some surplus was not uncommon in Ontario and other places and, although it still remains in many localities, its area has become restricted so much that it is no longer of great importance.

### Sage

Large amounts of surplus honey are secured from sage (genus *Salvia*) in California (Fig. 226). When that state was new a considerable part of

the honey which was shipped was from that source. There are three species of importance: the white sage (*Salvia apiana*), the black sage (*Salvia mellifera*), and the purple sage (*Salvia leucophylla*). Several others yield well but because of their sparseness and more restricted distribution are not known as well. Sage is practically unknown as a commercial source outside of California where cultivation is rapidly reducing its range in more settled areas, causing it to become the source of a much smaller part of the crop than in former years.

Sage honey is white, of heavy body, and of fine flavor. It is thought by some to be the finest honey obtainable and is regarded generally as the best honey on the Pacific Coast. It is a favorite with bottlers because it is slow to granulate.

### Mesquite

The most important source of honey in Texas and the Southwest is the mesquite (*Prosopis glandulosa*). Honey from the same or a closely related species comes from Hawaii under the name of "algaroba." Mesquite was once the most common tree from Texas through New Mexico to Arizona and eastern California. Over large areas it was the main source of honey for commercial apiaries. The honey is of light amber color and of good quality but no longer goes to market in the former quantity. Associated with it in former days was the catsclaw and huajillo, which produced honey of similar quality. In many cases the honey of all three were mixed and went to market by the name of the source most prominent in the neighborhood where it was produced. In areas where the land remains uncleared, much fine honey still comes from them but, as with other wild plants, the clearing of the land for cultivated crops has resulted in the disappearance of apiaries which depended on these sources.

### Tupelo

The tupelo (genus *Nyssa*) occurs in the South from southern Illinois and Virginia to Florida and Texas. As an important source of surplus honey it is confined to a relatively small area of swamps in southern Alabama and Florida. Along the Tombigbee and Apalachicola rivers heavy yields of tupelo honey are often secured, with apiaries of from 200 to 500 colonies on platforms high above the river banks to protect the bees from flood waters. The honey is in demand by bottlers because, when not mixed with other sources, it does not granulate. This quality combined with its heavy body and mild flavor insures a ready sale at relatively good prices.

### Gallberry

The gallberry (*Ilex glabra*) is a small evergreen shrub common to the low pine barrens of the Gulf Coast. Once the most important source of surplus in much of the coastal areas of the Carolinas, Georgia, Florida,

Alabama, Mississippi, and Louisiana, it gradually has been removed in some areas to give place to cultivated crops until it is no longer well known in some markets. Where abundant in undisturbed areas it is a very dependable source of nectar, yielding nearly every year. The crop comes in spring, May being the time of harvest. Gallberry honey is mild and distinctly flavored, slow to granulate, of amber color, and of heavy body.

### Fireweed or Willow Herb

The fireweed (*Epilobium angustifolium*) has seldom been important in any particular place for long (Fig. 227). It has yielded big crops for a short time following the removal of the forests in New York, Michigan, Wisconsin, Minnesota, and later in British Columbia, Washington, and Oregon. When trees are cut down there is usually a large amount of slash which burns readily. Once on fire, a large area is likely to be burned over leaving little but black waste. When this occurs the fireweed appears and covers the ground with a vast sea of pink flowers of unexcelled attraction to honeybees.

The blooming period is long and during the few years of its prosperity fireweed offers wonderful pasture for the honey producer. The honey is light in color and of fine quality.

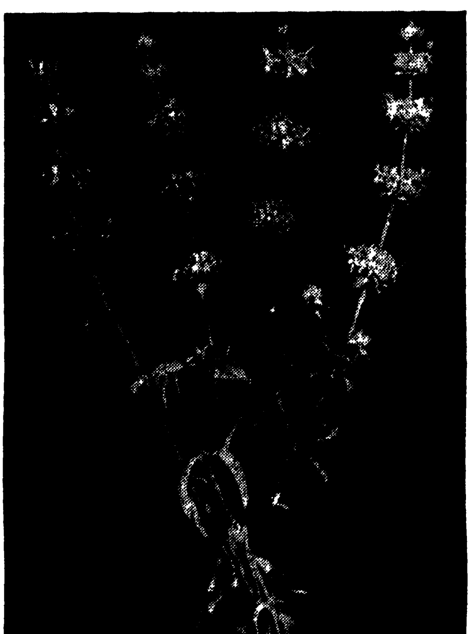


Figure 226. Black sage—the finest honey plant on the Pacific coast, although white and purple sages are also important. (*Photo by Homer Mathewson*)

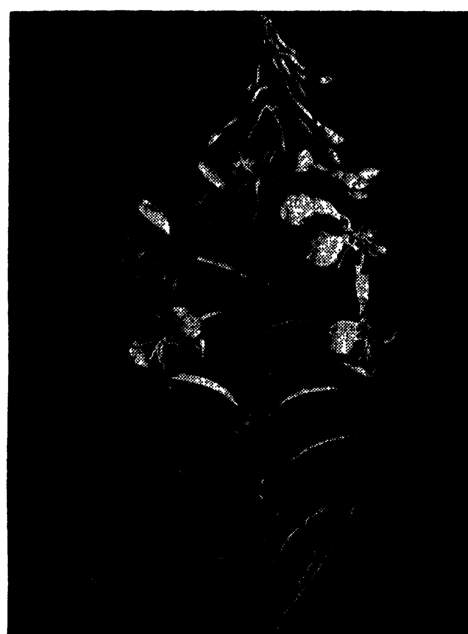


Figure 227. Fireweed, or willow herb, offers wonderful bee pasture during the few years of its prosperity in a burnt-over wooded area.

# Minor Sources of Surplus Honey

### Heartsease

Among the weeds are many that yield some honey, but only a few are sufficiently widespread for the honey to be well known on the market. The heartsease (*Polygonum persicaria*) and the related "smartweeds" occur over most of the United States and Canada. They are very common in late summer in stubble after grain is harvested and in cultivated fields where they continue to grow after cultivation has ceased.

There is a great variation in quality as well as in color of heartsease honey, but it is usually of pronounced flavor and of light amber color. Because of its habit of growth, the abundance of the plants varies from year to year, largely depending upon the available moisture supply, yet there is little danger of its permanent reduction or disappearance.

### Milkweed

In a few places good crops are harvested from milkweed (genus *Asclepias*). In northern Michigan there are places where milkweed is abundant and a crop of 100 pounds to the colony is not unusual. The honey is light in color and of good quality.

Figure 228. Early goldenrod, one of the many species that are widely distributed over North America—a fall source, yielding considerable honey in some places.

Figure 229. Asters comprise a very large group of related plants, some of which are important sources of honey in late fall. (*Photo by Paul Hadley*)

### Horsemint

The horsemints (genus *Monarda*) are widely distributed from New York to Minnesota and south to Florida and Texas. An occasional crop is obtained from them in many widely separated places but important yields seldom are reported except from the South, particularly Texas. The honey, amber in color and of inferior quality, is in little demand.

### Goldenrod

Plants of the genus *Solidago* are widely distributed with more than 80 species known to North America (Fig. 228). While yielding considerable honey in some places, there are large areas of several species of goldenrod where there is seldom enough nectar obtained from them to be recognized by the beekeeper. Lovell contended that probably all species of goldenrod yield nectar under favorable conditions. Honey in surplus quantity is reported from Louisiana where *Solidago altissima* is very common. In the sand hills of northern Nebraska some honey is gathered from *Solidago nemoralis*. Goldenrods are of most value in some of the Northern States, in eastern Canada, and in the New England States where they are the source of a deep golden honey of heavy body and decided flavor, granulating rather quickly but usually regarded as safe for winter stores for the bees.

### Aster

There are more than 200 species of the genus *Aster* (Fig. 229), of which more than 125 are found in this country. Most of them are attractive to bees although not always as a source of surplus honey. There is a large area in the Southeast, including portions of Kentucky, where asters provide a larger share of the crop than any other plant. There are so many different species so widely distributed that there are few localities where bees do not get something from asters. Little surplus, however, is reported west of the Missouri River.

Pure aster honey is often of light color and of good quality. Often the honey is mixed with that of other fall-blooming plants. Thus the quality is changed so much that there are many reports of poor quality honey from this source. Coming so late in fall it is sometimes poorly ripened which often makes it undesirable for winter stores.

### Spanish Needle

The Spanish needles (genus *Bidens*) are common to most grounds over a wide area, especially in the Eastern States. It is reported that a complete failure of honey from *Bidens trichosperma* and *Bidens laevis* along the Delaware River never has been known. In former years, before the drainage of the lowlands along the Mississippi and Missouri rivers and their tributaries, *Bidens aristosa* was the source of good crops of yellow

honey in late summer. Several other species are of local importance. Spanish needle honey is of good quality, slow in granulating, and of a distinct, pleasing flavor.

### Tulip Tree or Tulip Poplar

The tulip tree (*Liriodendron tulipifera*) is a large forest tree common to the Southeastern States (Fig. 230). It is of special importance in the region from Maryland to Alabama where it yields nectar freely in early spring. When colonies are strong, good crops are obtained but usually a large part of the possible crop is wasted because the colonies are too weak for this early harvest. The flow is dependable but often there is little other available pasture for a long period following the tulip-tree bloom.

### Persimmon

The persimmon (genus *Diospyros*) is a medium-size tree common to the Southeast from Virginia to Missouri and southward. Although nowhere of first importance, it is widely known as a dependable source of honey. It blooms in May and attracts bees in large numbers. It yields freely but the flow is rather short. Yields as high as 75 pounds per colony are reported.

## Sources of Importance in Limited Areas

### Wild Thyme

In a few localities in southwestern Vermont, in Massachusetts, and in New York the wild thyme (*Thymus serpyllum*) carpets the roadsides for miles and is abundant in pastures and on hillsides. There the beekeeper gets good crops of a light amber, spicy or minty honey of good flavor similar to the famous honey from Mount Hymettus in Greece. Yields as high as 125 pounds to the colony often are secured.

### Lima Bean

The lima bean is the source of much surplus honey in a few counties in southern California but is rarely reported elsewhere. Ventura County, California, formerly was considered the source of more than 60 per cent of the lima beans raised in this country. Beekeepers in the vicinity of the fields harvested dependable crops of from 40 to more than 100 pounds of white honey per colony, of good flavor but granulating readily.

### Carrot and Onion

In the seed belt of California, a few beekeepers find favorable locations near seed farms where good crops are gathered from both carrots and onions. The honey from onions is of fair quality while that from carrots is inferior. Numerous other vegetables and garden flowers provide pasture for those fortunately located.

### Palmetto

The palmettos (genus *Sabal*) are the most typical feature of the Florida landscape. The cabbage palmetto is found to some extent in adjacent areas of Georgia and South Carolina, and dwarf species are found along the coast to Louisiana and Texas.

The cabbage palmetto blooms in midsummer and is a source of large crops of high-quality honey. When first stored the honey is rather thin and care is necessary to insure proper ripening. The saw palmetto blooms in late spring and the flow continues into May. The honey is yellow in color, thick, and of delicious flavor. Few distinguish between the various species of dwarf palmettos and all apparently are a source of honey in the Gulf Coast area. Yields up to 200 pounds per colony have been reported from Louisiana.

### Mangrove

The black mangrove (*Avicennia nitida*) is an evergreen tree growing in shallow water along the coast of Florida. It is found only in the vicinity of salt water and varies from a small shrub to a tall tree. It blooms in June and July, is erratic in its yield, and may give but scant crops for several years and then produce an enormous return. Yields of from 300 to nearly 400 pounds per colony have been reported. The honey is light colored and mild flavored.

### Sourwood

The sourwood (*Oxydendrum arboreum*) is a well-known tree growing on acid soils in the mountains from West Virginia to northern Georgia, and west to Arkansas. Beekeepers in that area boast that sourwood honey is the finest honey known to America. Those accustomed to mild-flavored, light honey from clovers do not always agree, but the local demand readily consumes the crop so that little is found in markets of distant cities. The honey harvest comes in midsummer and lasts 2 to 3 weeks. The honey is heavy in body and of pronounced flavor.

### Other Sources in Limited Areas

Black locust, a widely distributed tree, is important for honey in restricted areas (Fig. 231). The flowering period is so short that it is seldom that a good crop is gathered from it, but when conditions are favorable it sometimes yields heavily for a few days. The honey is of good quality and of mild flavor. The honey locust is little known as a source of surplus honey although the bees work the flowers heavily for a few hours. The short period of bloom limits the value of both of the locusts for bee pasture.

There are many other plants that yield nectar locally that are scarcely known outside of a limited area. The mountain maple of Michigan and

FIGURE 230. Tulip tree, or tulip poplar, is a dependable and plentiful source of nectar in early spring in the Southeast. (*Photo by Edgar Abernethy*)

FIGURE 231. The bloom of the black locust —a minor source of nectar in early spring under favorable conditions. (*Photo by Paul Hadley*)

New York is an example. California has a long list of plants important only locally, such as eucalyptus, incense cedar, wild buckwheat, and star thistle. A list of such sources could be extended beyond the limits advisable in a book like this. Hundreds are discussed at length in books devoted to honey plants.[7, 8]

## Sources Valuable for Colony Support

Among the plants of special importance for colony maintenance, the dandelion (*Taraxicum officinale*) probably stands in first place (Fig. 232). It is found in every part of the country and blooms in great abundance when incoming pollen and nectar are of great value. The flowering of the dandelion provides an ideal stimulus and brood rearing expands amazingly. It yields pollen plentifully and an abundance of nectar. Only rarely is surplus honey reported from dandelion because colonies are usually small when it blooms, but it does prepare the bees for later flows from other plants.

---

[7]Pellett, Frank C. 1947. *American Honey Plants.* 4th ed. New York, N. Y. Orange Judd Publishing Co., Inc.

[8]Lovell, John H. 1926. *Honey Plants of North America.* Medina, Ohio. The A. I. Root Co.

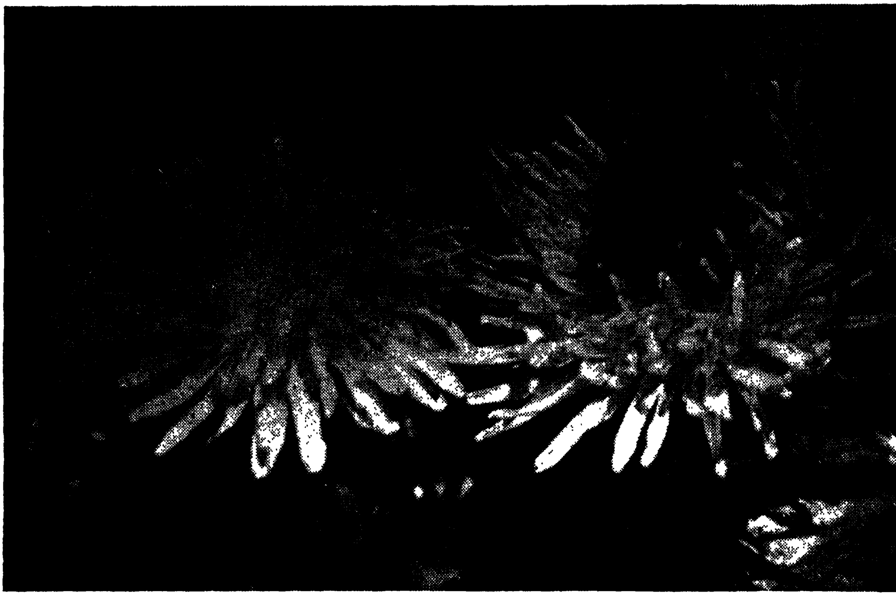


FIGURE 232. Dandelion—a nuisance in the lawn but an important spring source of nectar and pollen for the honey bee, blooming when colonies need every boost they can get. (*Photo courtesy Paul Hadley*)

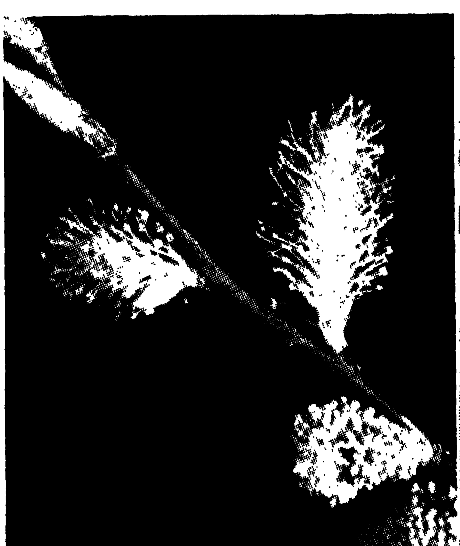


FIGURE 233. Willow buds in various stages of blooming—one of the earliest sources of nectar and pollen for the honey bee. (*Photo by Ben Knutson*)

FIGURE 234. Maples usually bloom before the orchard blossoms in spring, and may produce a surplus of honey when conditions are favorable.

Of similar importance are the various species of willow (genus *Salix*), one or more of which are present in nearly every section where beekeeping is practiced (Fig. 233). While willow is occasionally reported as the source of a little surplus, it is of greatest value for spring brood rearing. In most places, especially in the North, the willows bloom early and supply both nectar and pollen when they are needed most for stimulation.

Blooming at the same season and over much the same wide range of territory are the maples which yield nectar in great abundance for a brief time (Fig. 234). Often the flowers are caught by frost so that in many cases bee pasture will be available for only a few hours. They yield so freely, however, that even with a few hours of sunshine the bees secure great benefit. Sometimes overlapping the maple bloom, but usually somewhat later, come the blossoms of the orchard fruits which might provide a large surplus of honey if they came when settled weather and strong colonies made it possible to fully utilize the nectar.

Red clover (*Trifolium pratense*) usually is of little importance as a source of honey to the beekeeper since under ordinary conditions the flower tubes are too deep for the bees to reach the nectar. However, the plant is a good source of pollen and often the bees visit it freely. At times some surplus honey is secured.

## Honeydew

Aphids, scale insects, and leaf hoppers sometimes are found on trees or plants in such numbers that the honeydew which they excrete is in such quantities that it covers surrounding objects at a lower level with its sticky drops. When natural sources are lacking, the bees may actually gather, store, and even seal honeydew in their combs. The product is inferior and generally is in little demand being used only where quality is of no importance. For additional information on honeydew and honeydew honey, see Chapter XV, "Honey."

## Honey Plant Test Garden

In the spring of 1937, the *American Bee Journal* established a honey plant test garden on the farm of Field Editor Frank C. Pellett, at Atlantic, Iowa (Fig. 235). The object was to find new plants rich in nectar which might find a place in farm rotation or commercial gardens and thus provide more bee pasture.

The first season brought the Zofka red clover to public attention. Dr. Zofka, of Czechoslovakia, had spent many years in selecting a red clover with short corolla tubes which would permit honey bees to reach the nectar. Seed was secured direct from Dr. Zofka and planted in May. The plant made a good growth, bloomed freely, and attracted the bees in a

way to offer much encouragement. Measurements of the flower tubes by Dr. J. N. Martin, of Iowa State College, showed them to be much shorter than those of common red clover. They ranged from 5 to 8 millimeters in depth in comparison with 9 to 11 for other red clover. A plot an acre in extent was planted the following year but was winterkilled the next winter. Other trials resulted in similar failures.

Altogether more than 20 species of lespedezas have been tried in hopes of finding one which would yield nectar freely and be suitable as forage for livestock. *Lespedeza bicolor* and *Lespedeza cyrtobotra,* shrubby lespedezas from Asia, are very attractive to bees but too coarse for forage other than for browse on land suitable only for permanent pasture. The commonly cultivated lespedezas are of little value for honey.

Among the legumes, bird's-foot trefoil (*Lotus corniculatus*) has proved drought resistant, long lived, and a valuable addition to the forage crops of the Midwest. Ladino clover, commonly grown in the East, has also proved promising (Fig. 236). It makes a fine quality hay, good pasture, and secretes nectar freely. It grows much like white Dutch clover and does best where moisture is abundant. A half pound of seed to the acre, mixed with a suitable grass, or with other clovers, gives the grower a wonderful hay mixture.

Of the nearly one hundred legumes, *Trifolium ambiguum* (now called Pellett clover by some), a deep-rooted perennial from the Caucasus and steppes in Europe, stands above all others as entirely new and different from any other legume now under cultivation. It spreads rapidly by rhizomic roots and appears to be winter hardy, and indications are that it will have wide use. It looks much like alsike, the flowers being about the same color but larger. The corolla tube is shallow, freely yielding nectar that is available to the honey bee.

## Promising Native Plants

Among native plants three offer great attraction for the bees: anise-hyssop, wood mint, and mountain mint.

Anise-hyssop (*Agastache foeniculum*), which was once common over a wide area in the North Central States, has largely disappeared in the wild. It comes into bloom early in June and some plants are still blooming when killed by frost in October. The bees visit the flowers more consistently than any other plant so far observed. Whether it be early morning or late evening, clear or cloudy, warm or cool, the bees eagerly seek the abundant nectar. Numerous measurements of the sugar content of the nectar under different weather conditions, by Dr. O. W. Park, have shown the average sugar content to be high, some samples containing as much as 58 per cent sugar.

Wood mint (*Blephilia ciliata*), which generally has been overlooked by the gardeners as a very desirable ornamental, is a valuable source of

FIGURE 235. Frank C. Pellett and his grandson examining some of the plantings in a part of the *American Bee Journal* honey plant test garden at Atlantic, Iowa.

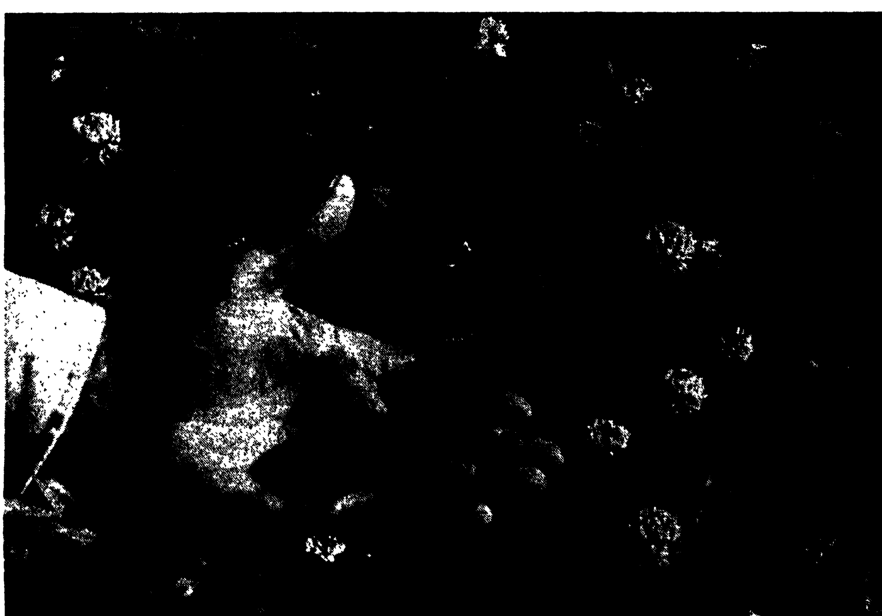


FIGURE 236. Ladino clover, commonly grown in the East, makes good pasture and hay, and provides nectar for the bees. (*U.S.D.A. photograph by Harmon*)

bee pasture. Found only in partially shaded areas in woodland borders, it is rarely sufficiently plentiful to be important in the wild. Thus far, there is no indication that it might serve any useful purpose other than as an ornamental.

The mountain mint *(Pycnanthemum pilosum)* is very promising as a source of essential oil. Samples from the honey plant test garden, which have been distilled by Prof. Arthur Schwarting of the Nebraska College of Pharmacy, return an oil which contains pulegone as its major ingredient. Results indicate that this plant may prove profitable as a commercial source of essential oil.

## Planting for Bee Pasture

With so many changes in farm practice it has become necessary for the beekeeper to find ways to increase the available bee pasture. Generally, it is thought to be unprofitable to cultivate plants for bee pasture alone. However, it often is possible to combine bee pasture with the production of crops for other purposes. The clovers or alfalfa can be grown for seed, as well as for bee pasture, and together a substantial profit is obtained under favorable conditions. Ladino clover is another legume which is finding favor in many new places because it yields good profits to seed growers. Others have found that bird's-foot trefoil offers very good returns from the seed crop while giving a satisfactory yield of honey. Beekeeper-farmers, who have made such plantings, have reported that sufficient income was obtained from the sale of seed to make the venture worth while, even when the honey crop was poor.

In addition to cultivated lands, there are many places where there are large areas of unused or wastelands which can be utilized for plantings of honey plants. The hundreds of miles of roadsides also can be turned to good advantage through co-operation with the highway authorities. The varieties of plants and trees used in plantings along the thousands of miles of highways will have a great influence on the long-time returns of apiaries. The various wildlife commissions also are interested in co-operating in programs of this kind.

### Trees for Bees

A beekeeper who has bees near Kensington Gardens in the heart of London and another apiary in the country reports twice as much honey obtained by the bees in the city of London. Extensive parks can provide good bee pasture if the right ornamentals, shrubs, and trees are planted.

The maples are highly ornamental trees and all yield nectar and pollen in abundance. The willows likewise provide much early forage. Of the many species of maples and willows, some are suited to nearly every section of America. The basswoods make beautiful specimen trees and at times yield nectar abundantly. In the East the tulip tree is un-

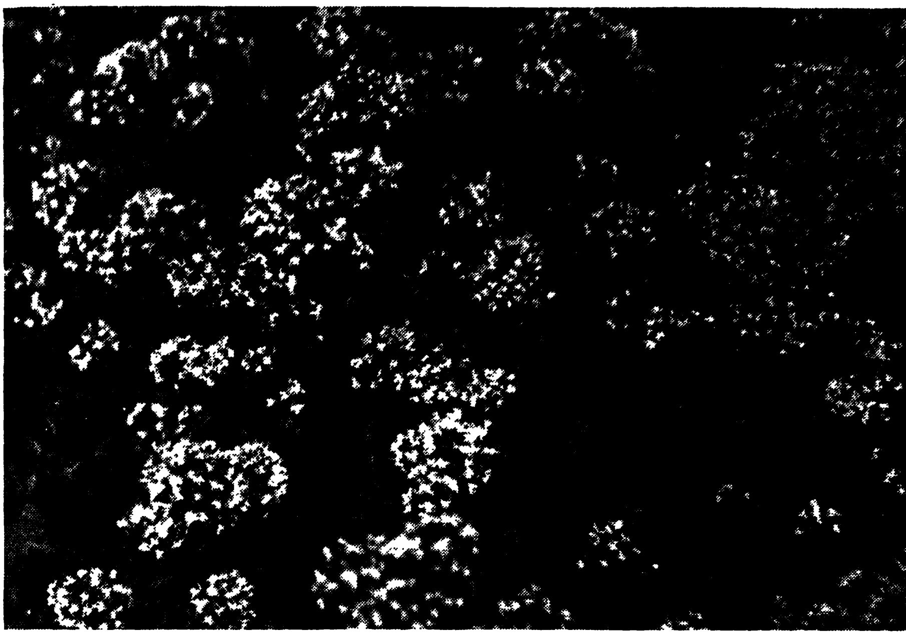


FIGURE 237. Marjoram, recommended for control of soil erosion, is a midsummer nectar source. It blooms profusely, its white to red flowers making a pleasing sight.

surpassed, both as an ornamental and as a nectar yielder. The persimmon tree attracts the bees in great numbers during its period of bloom. The wild cherries yield nectar for the bees and fruit for the birds. The pagoda tree *(Sophora japonica)*, while slow growing, is highly desirable for the bees.

For the warmer parts of the country, Florida, the Gulf Coast, and the lower Rio Grande Valley, the cajeput tree *(Melaleuca leucadendra)* is very desirable and is a source of abundant nectar. For the hot and dry areas of Arizona and the adjacent territory, the Athel tree *(Tamarix aphylla)*, which comes from North Africa, is to be recommended. In California the various species of eucalyptus are much used. In Texas the tallow tree *(Sapium sebiferum)* is well suited to highways. An entire chapter could be devoted to discuss in detail the trees of benefit to bees. For further information, the reader is referred to the books on honey plants.

### PLANTS FOR ROADSIDES

Of first importance for roadside plantings are such legumes as white Dutch clover, alsike clover, and bird's-foot trefoil. There is likely to be objection to the sweet clovers because they grow tall and are weedy in appearance.

Where newly worked soil offers opportunity to plant on a well-prepared seed bed there are three low-growing plants which are attractive

in appearance, adding beauty to the landscape while providing good bee pasture: the meadow sage, the summer sage, and marjoram. A mixture of these three distributed along the roadsides would go far to stabilize the bee pasture of a neighborhood.

The meadow sage *(Salvia pratensis)* is entirely hardy in the cold climates of the Northern States, and it is apparently equal to the sages of California for honey. It comes into bloom when fruit blossoms and dandelions are fading and continues through May and early June. It thus fills a gap when little forage generally is available and sustains the bees until the clover flow.

Following the meadow sage comes the summer sage *(Salvia superba)* which blooms through June and early July, and flowers a second time in late summer. When the flowers are open, the bees are attracted to them in great numbers. From England comes a report that the bees visit this species in Kew Gardens in such numbers as to give the impression of a swarm alighting or in the vicinity.

In midsummer the marjoram (*Origanum vulgare*) blooms for several weeks in great abundance at a time when there is a serious dearth of nectar in many localities (Fig. 237). Marjoram spreads slowly from the root but is quite persistent when once established, and is able to withstand competition of grasses and other vegetation. It is highly desirable for erosion control. The color of the flowers varies from white to dark red and mass plantings give a very pleasing effect.

### Plants for Waste Places

For strip mines, broken hillsides, and wastelands the shrubby lespedezas, although coarse and woody, provide good erosion control, splendid game cover, and an abundance of late bee pasture. On such areas, or in partially shaded pastures, the crownbeard (*Actinomeris alternifolia*), which many beemen call the "golden honey plant," is a long-lived, late-flowering plant which yields nectar abundantly. The figwort *(Scrophularia marilandica)*, while weedy in appearance, offers no problem in weed control and is famous for its attraction for the bees. Catnip, motherwort, horehound, and spearmint also are desirable for planting on lands which are not suitable for pasture or cultivation.

Purple loosestrife, or purple lythrum *(Lythrum salicaria)*, is the one plant which can be planted with confidence in boggy spots and generally on wet lands. It flowers freely in midsummer, yields nectar in abundance, and large crops of honey are reported in a few localities. For sandy soils the horsemints and pleurisy root or Indian posey (*Asclepias tuberosa*) are to be recommended. The latter is one of the milkweeds and was famous as a source of honey in pioneer days before the wild plants generally had been destroyed. For the Southland where there is little frost, the coral vine or pink vine (*Antigonon leptopus*) is famous for its attraction for bees.

# XIX. *The Anatomy of the Honey Bee*

BY R. E. SNODGRASS*

THE ANATOMY of an animal is the assemblage of structural parts that enables the animal to do the things necessary for the maintenance of its individual existence, and for the perpetuation of its kind. As an individual the animal must obtain and distribute to its tissues both food and oxygen, eliminate waste matter, and correlate the activities of its various organs with one another and its own activities with changing conditions of the environment. Hence the animal has a locomotor system, feeding and digesting organs together with a system of food distribution, a respiratory system, an excretory system, and a nervous system. To provide for the continuance of its species it has a reproductive system. In addition, nearly every animal has some specialty of its own—it may eat only a particular kind of food, it may inhabit a special kind of environment, it may adopt a particular method of locomotion, it may be individualistic or socialistic—and according to its habits or its way of life it is equipped with special anatomical mechanisms.

The honey bee is constructed on the general plan of an insect, but it leads a highly specialized kind of life and for this reason is provided with special mechanisms and gadgets that enable it to live in its particular way. Hence, in studying the bee, while we must give attention to its fundamental insect organization, special interest pertains to the structures and modifications of organs that adapt the bee to its manner of living and differentiate it from other insects.

In its general structure the bee resembles any other insect, though its form (Fig. 238) is obscured by the dense coating of hairs with which the body is covered. The bee's coat is particularly fluffy because most of the hairs are featherlike, the shaft of each hair having many short side branches.

The *head* of the insect (Fig. 238, *H*) carries the eyes, the antennae, and the organs of feeding. It is joined to the next body division, the *thorax* (*Th*), by a slender flexible neck. The thorax and the third section of the trunk, or *abdomen* (*Ab*), are composed of a succession of rings called *segments*. In most insects the thorax consists of only three segments, but in the bee and related insects it includes four segments which

*Robert E. Snodgrass. Collaborator, Bureau of Entomology and Plant Quarantine, U. S. D. A. Formerly assistant professor of entomology, State College, Washington. Author of *Anatomy of the Honeybee*. World authority on insect morphology.

are the *prothorax* (1), the *mesothorax* (2), the *metathorax* (3), and the *propodeum* (*I*). The propodeum of the bee is the first abdominal segment of most other insects. The prothorax carries the first pair of legs ($L_1$); the mesothorax and the metathorax, in addition to carrying each a pair of legs ($L_2$, $L_3$), support also the two pairs of wings ($W_2$, $W_3$). The thorax is clearly the locomotor center of the insect. A short stalk, the *peduncle,* attaches the thorax to the abdomen which contains the principal internal organs.

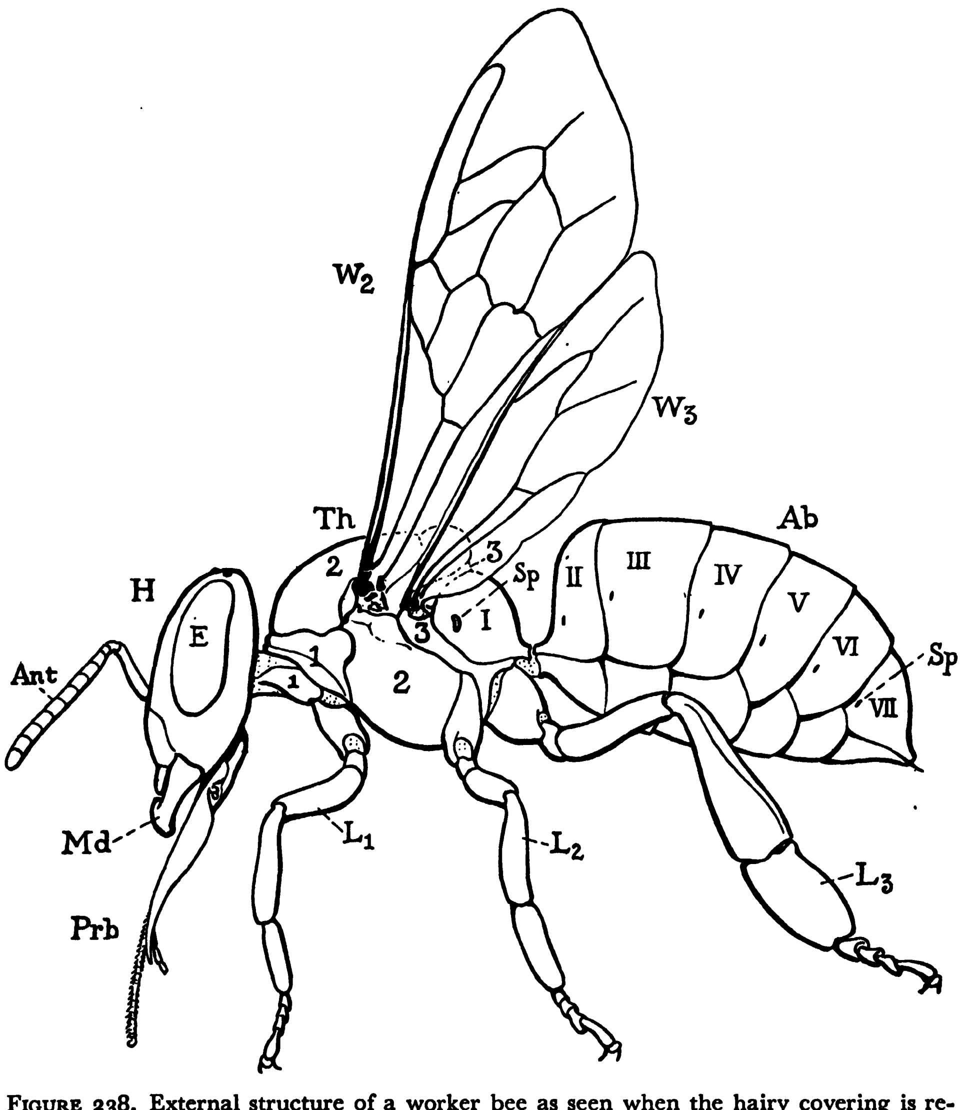



FIGURE 238. External structure of a worker bee as seen when the hairy covering is removed. *Ab,* abdomen; *Ant,* antenna; *E,* compound eye; *H,* head; *I,* propodeum; *II-VII,* abdominal segments; $L_1$, $L_2$, $L_3$, legs; *Md,* mandible; *Prb,* proboscis; *Sp,* spiracle; *Th,* thorax; $W_2$, $W_3$, wings; *1,* prothorax; *2,* mesothorax; *3,* metathorax. (*Drawing courtesy Bureau of Entomology and Plant Quarantine*)

The feeding organs of the bee consist of the same parts as do those of a grasshopper or a cricket, but the parts are very different in form because in the bee they are adapted to the ingestion of pollen, as well as of liquid food to be obtained from the depths of flower corollas, while such insects as grasshoppers and crickets merely bite off, chew, and swallow particles of solid food.

The wings of the bee are adapted for swift flight and also for sustaining a load. The legs are modified in their structure for various uses besides that of locomotion. The sting of the bee represents the ovipositor of other female insects, sufficiently remodeled in structure to serve for piercing and for the injection of poison instead of eggs.

Most of the internal organs of the bee are much the same as in other insects, but the alimentary canal has a special adaptation for carrying nectar or honey. The respiratory system is greatly amplified. In the queen the ovaries are so highly developed as to be capable of producing a great number of eggs which can be discharged continually over long periods of time. Special glands of the head produce a rich food substance for the brood. Glands of the abdomen form wax for comb building. Near the end of the body is a gland that secretes a scent by which bees get information from one another.

## The Head, the Antennae, and the Organs of Feeding

Though the head of an insect is a craniumlike structure with continuous walls, its embryonic development shows that it is formed by the close union of several segments like those of the thorax and abdomen. The segmental structure of the head, moreover, is attested by the fact that the head carries four pair of appendages. These appendages are the *antennae,* the *mandibles* or jaws of the insect, the *maxillae,* and the *labium,* which last represents a second pair of maxillae united. In the bee the maxillae and the labium together form the *proboscis,* an organ for feeding on liquids. The head bears also the eyes, usually a pair of large lateral *compound eyes* and, between the latter, usually three small simple eyes called *ocelli.*

### Structure of the Head

The head of the honey bee is triangular as seen from in front (Fig. 239, *A*), flattened from before backward, somewhat concave on the posterior surface (*B*), and is set on the thorax by a narrow membranous neck. The lateral angles are capped by the compound eyes (A, *E*), and on the top of the head are three *ocelli* (*O*). The antennae (*Ant*) arise close together near the center of the face. Below their bases a prominent arched groove (*es*) sets off a large area known as the *clypeus* (*Clp*), from the lower margin of which is suspended a broad movable flap, the *labrum* (*Lm*). Attached laterally to the lower part of the head behind the labrum are

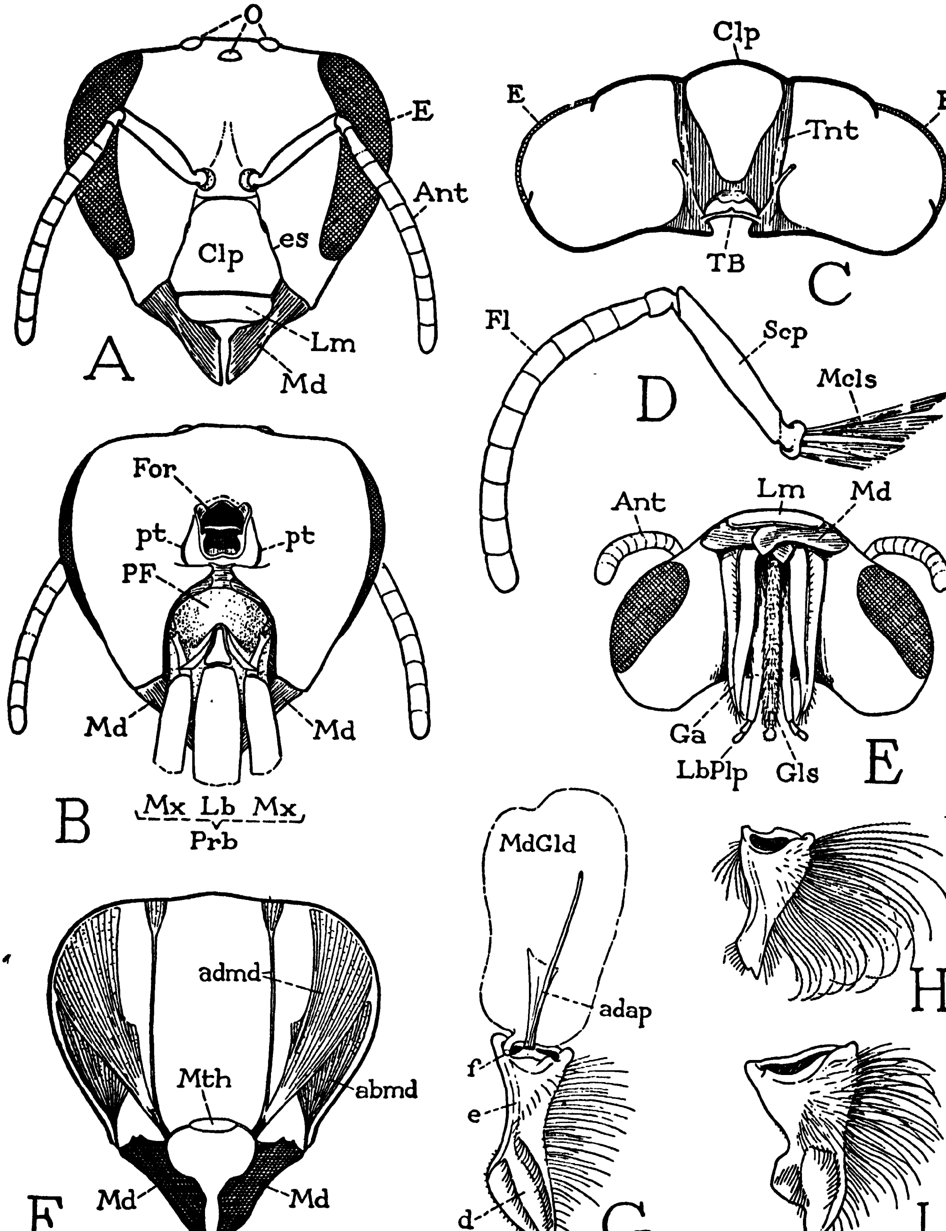



FIGURE 239. The head, antennae, and mandibles of a worker bee (except H and I). A, facial view of head. B, rear view of head. C, horizontal section of head showing internal tentorium. D, antenna. E, under view of head and folded proboscis. F, transverse vertical ection of head showing mandibles and their muscles. G, mandible and mandibular gland, mesal view. H, mandible of drone. I, mandible of queen.

*abmd*, abductor muscle of mandible; *adap*, tendon of abductor muscle of mandible; *admd*, adductor muscle of mandible; *Ant*, antenna; *Clp*, clypeus; *d*, channel of mandible;

the two jawlike mandibles *(Md)*, and behind the mandibles, better seen from the back of the head (B), are suspended the two maxillae (*Mx*) and the median labium (*Lb*). The long distal parts of the maxillae and labium, shown spread out at A of Fig. 240, either project downward or are folded back below and behind the head (Fig. 239, *E*); but in their functional position they are brought together to form a tubular proboscis (Fig. 238, *Prb)* for feeding on liquids.

On the back of the head, as seen when it is detached from the body (Fig. 239, *B*), is a central opening, the *neck foramen (For)*, by which the cavity of the head communicates with that of the body, and which gives passage for the oesophagus, nerves, blood vessel, air tubes, and salivary duct. Below the foramen the hard wall of the head is cut out in a large horseshoe-shaped notch with a membranous floor in which are implanted the long bases of the maxillae and labium. The depression of the notch, therefore, is designated the *proboscis fossa* (*PF*).

Internally the walls of the head are braced by two large bars (Fig. 239, C, *Tnt*) that extend through the head cavity from the sides of the neck foramen to the grooves of the face at the sides of the clypeus (*Clp*). The posterior ends of the bars are bridged by a slender cross-rod *(TB)*, which may be seen from behind just within the neck foramen (B). The bars and the connecting bridge constitute the *tentorium.*

## The Antennae

The antennae are freely movable appendages with their bases set into small socketlike membranous areas of the head wall (Fig. 239, A). Each antenna is pivoted on a single articular point of the socket rim, and is provided with four muscles (D, *Mcls*) arising on the tentorial bar of the same side of the head. Each appendage, moreover, has an elbowlike joint between its basal stalk, or *scape (Scp)*, and the flexible distal part called the *flagellum (Fl)*. The scape of the drone antenna is shorter than that of the worker, but the flagellum is much longer and consists of 12 short rings, while there are only 11 in the worker and the queen. The antennae are important sensory organs. Each appendage is penetrated by a large double nerve from the brain. The flagellum is covered with small innervated hairs and other minute sensory structures of several kinds. It is difficult to determine the particular function of each variety of sense organ, but the antennae are responsive particularly to stimuli of touch and odor.

---

*e*, groove of mandible; *E*, compound eye; *es*, suture defining clypeus; *f*, orifice of mandibular gland; *Fl*, flagellum; *For*, neck foramen of head; *Ga*, galea; *Gls*, tongue (glossa); *Lb*, labium; *LbPlp*, labial palpus; *Lm*, labrum; *Mcls*, muscles; *Md*, mandible; *MdGld*, mandibular gland; *Mth*, mouth; *Mx*, maxilla; *O*, ocelli; *PF*, proboscis fossa; *Prb*, proboscis; *pt*, posterior tentorial pit; *Scp*, scape; *TB*, tentorial bridge; *Tnt*, tentorium. (*Drawing courtesy Bureau of Entomology and Plant Quarantine*)

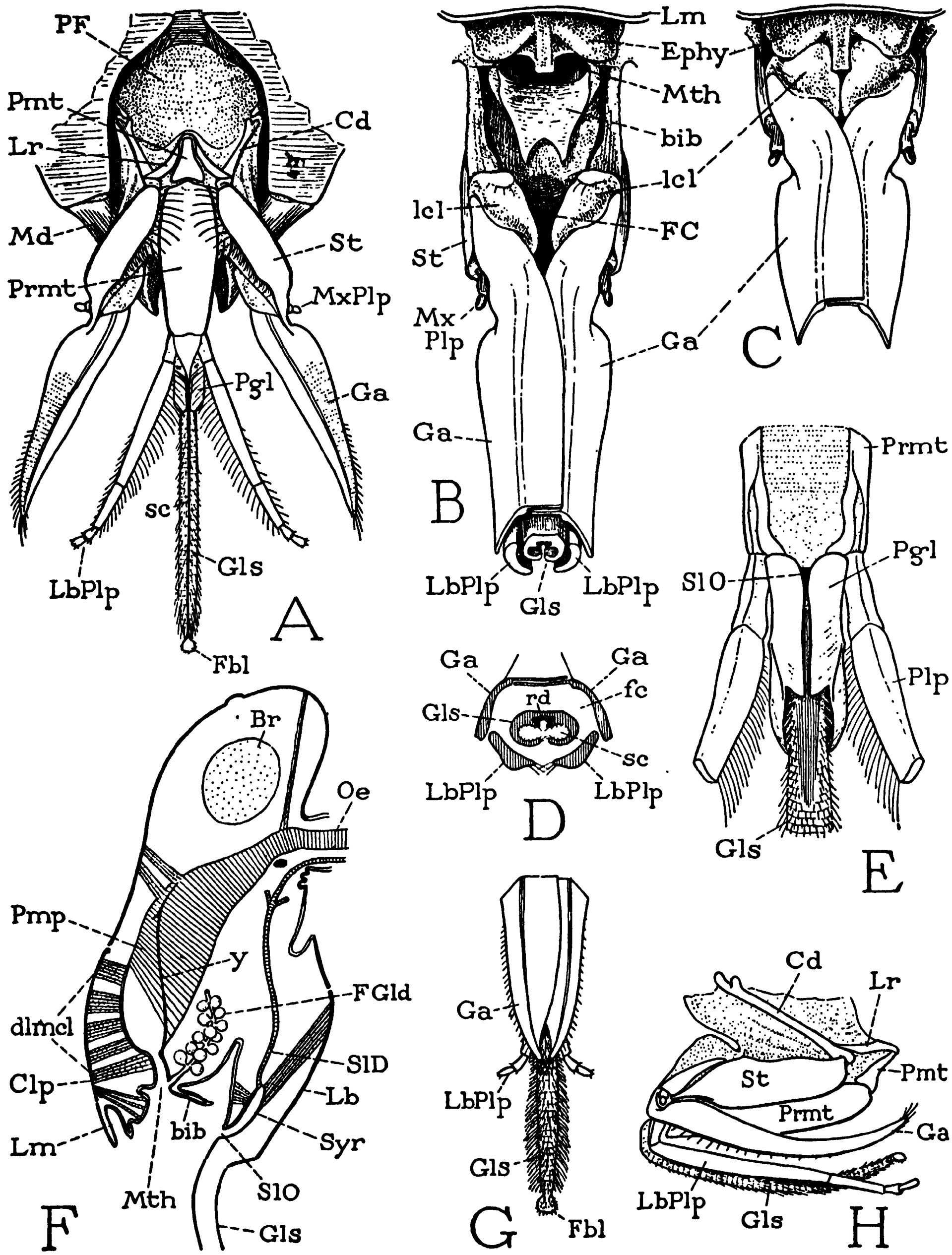



FIGURE 240. The proboscis and the sucking apparatus of a worker bee. A, proboscis, seen from behind, with its parts artificially spread out. B, front view of base of proboscis pulled down from head, exposing mouth (*Mth*) and deep food channel (*FC*) leading up to mouth. C, same, food channel closed by base of proboscis brought up against the mouth. D, cross section through middle of proboscis. E, base of tongue, paraglossae, labial palpi, and distal end of labial prementum, anterior view. F, lengthwise vertical section of head showing sucking pump (*Pmp*), salivary syringe (*Syr*), and associated structures. G, distal

## The Mandibles

The mandibles (Fig. 239, A, *Md*) are suspended from the head at the sides of the mouth (F, *Mth*), which lies immediately behind the base of the labrum. Each jaw has an anterior and a posterior point of articulation on the head, and is provided with only two muscles (F, *abmd, admd*) which are attached on opposite sides of the axis of movement. The mandibles therefore swing sideways; but, because the anterior articulations are higher than the posterior, the points of the jaws turn inward and backward when the mandibles close.

The mandible of the worker bee (Fig. 239, G) is thick at the base, narrowed through the middle, and widened again distally in an expansion with a concave inner surface traversed by a median channel *(d)*. From the channel a groove (*e*) runs upward to an aperture (*f*) at the base of the mandible, which is the outlet of a large, sacklike *mandibular gland* (*MdGld*) that lies in the head above the mandible. The gland secretes a clear liquid, the purpose of which is not definitely known, but the secretion is supposed to be used for softening wax. The mandibular glands are largest in the queen; in the drone they are reduced to small vesicles. The worker bee uses its mandibles for eating pollen, for working the wax in comb building, for holding the base of the outstretched proboscis, and for doing any of the chores about the hive that require a pair of grasping instruments. The mandibles of the queen (Fig. 239, *I*) are larger than those of the worker but they lack the special features of the worker mandibles and each has a broad inner lobe near the pointed apex. The drone mandibles *(H)*, on the other hand, are smaller than those of the worker, and each is sharply notched at the base of the apical point.

## The Proboscis

The proboscis of the bee is not a permanently functional organ as it is in most other sucking insects; it is temporarily improvised by bringing together the free parts of the maxillae and the labium to form a tube for ingesting liquids—nectar, honey, or water. The maxillary and labial components of the proboscis are closely associated at their bases, which are suspended in the ample membrane of the fossa on the back of the head (Fig. 240, *A*). The base of the median labium includes a long, cylindrical distal part termed the *prementum* (*Prmt*), and a small, triangular proxi-

---

part of proboscis with tongue protruded. H, side view of proboscis folded beneath head. *bib*, biblike fold from lower lip of mouth; *Br*, brain; *Cd*, cardo; *Clp*, clypeus; *dlmcl*, dilator muscles of sucking pump; *Ephy*, epipharynx; *Fbl*, flabellum; *fc*, food canal of proboscis; *FC*, food channel on base of proboscis; *FGld*, food gland; *Ga*, galea; *Gls*, tongue (glossa); *Lb*, labium; *LbPlp*, labial palpus; *lcl*, lacinial lobe of maxilla; *Lm*, labrum; *Lr*, lorum; *Md*, mandible; *Mth*, mouth; *MxPlp*, maxillary palpus; *Oe*, oesophagus; *PF*, proboscis fossa on back of head; *Pgl*, paraglossa; *Plp*, labial palpus; *Pmp*, sucking pump; *Pmt*, postmentum; *Prmt*, prementum; *rd*, rod of tongue; *sc*, salivary canal of tongue; *SlD*, salivary duct; *SlO*, orifice of salivary duct; *St*, stipes; *Syr*, salivary syringe. (*Drawing courtesy Bureau of Entomology and Plant Quarantine*)

mal plate, the *postmentum (Pmt)*. The prementum carries at its end the slender hairy *tongue (Gls)*; a pair of short lobes, the *paraglossae (Pgl)*, embracing the base of the tongue; and a pair of slender *labial palpi (LbPlp)*. Each palpus consists of two long basal segments and two short apical segments, and is individually movable by a muscle arising in the prementum. In each maxilla the principal basal plate (A, *St*) is the *stipes* (plural *stipites*), but the stipes is suspended by a slender rod *(Cd)*, the *cardo* (plural *cardines*), that articulates with a knob on the margin of the proboscis fossa. The distal ends of the two cardines are yoked to the postmentum of the labium by a V-shaped sclerite known as the *lorum (Lr)*. Each stipes carries a long, free, tapering, bladelike lobe, the *galea (Ga)*, and, arising lateral to the galea, a very small maxillary palpus *(MxPlp)*.

When the proboscis is not in use its basal parts are drawn up behind the head by swinging on the suspending cardines (Fig. 240, H), while at the same time the distal parts are folded back against the prementum and stipites. When the bee would imbibe liquid, the proboscis is protracted by swinging downward on the cardines, and its distal parts are extended. The broad maxillary galeae and the labial palpi are brought together around the tongue (Fig. 240, B, G) in such a manner as to form a tube (D), closed anteriorly by the overlapping galeae *(Ga)* and posteriorly by the palpi *(LbPlp)*, with the tongue *(Gls)* occupying an axial position and projecting beyond the enclosing parts (G). The two small end-segments of the palpi diverge at the end of the tube and probably have a sensory function. The tongue now begins a rapid back-and-forth movement, while its flexible tip is swung around with an agile lapping motion. Apparently by the action of the tongue the liquid food is drawn up into the canal of the proboscis (D, *fc*).

The long hairy tongue of the bee is an extension from the end of the labial prementum (Fig. 240, A, *Gls*). It has a closely cross-lined appearance owing to the presence in its wall of hard rings bearing the hairs, separated by narrow, smooth, membranous intervals. Because of this structure the tongue can be shortened and lengthened. On its base is a bonnet-shaped plate (Fig. 241, A) supported on a pair of arms (*b*) which are extensions of two straplike bars in the side walls of the prementum (D, *a*). The under or posterior side of the tongue is traversed by a deep groove (Fig. 240, A, *sc*) with thin membranous walls, through the middle of which runs a long rodlike thickening (D, *rd*) which is grooved on its free surface. At the tip of the tongue the rod ends in a small spoon-shaped lobe, the *flabellum* (A, G, *Fbl*), that has a smooth, rounded under-surface but is armed on the margin and the upper surface by minute branched spines. Basally the tongue rod curves backward to be firmly attached to the end of the posterior wall of the prementum (Fig. 241, A), and on this curved part are inserted two long muscles (20) arising in the prementum. It is the pull of these muscles on the basal curvature of the

rod that shortens the tongue (B); extension is due apparently to the elasticity of the rod which straightens again when the muscles relax. Thus are produced the movements of protraction and retraction of the tongue from the end of the proboscis; but since the rod lies close to the posterior margin of the tongue its retraction gives the tongue also a slight backward curvature (B). The lapping motion of the tongue tip evidently is produced by the rod muscles acting separately in opposition to each other.

The food canal of the proboscis leads up into a channel on the base of the proboscis between the bases of the two maxillae and the labium, which appears as an open troughlike cavity when the proboscis is lowered from the head (Fig. 240, B, *FC*). At the upper end of this channel is the *mouth (Mth)* partly hidden behind a large soft lobe, the *epipharynx*

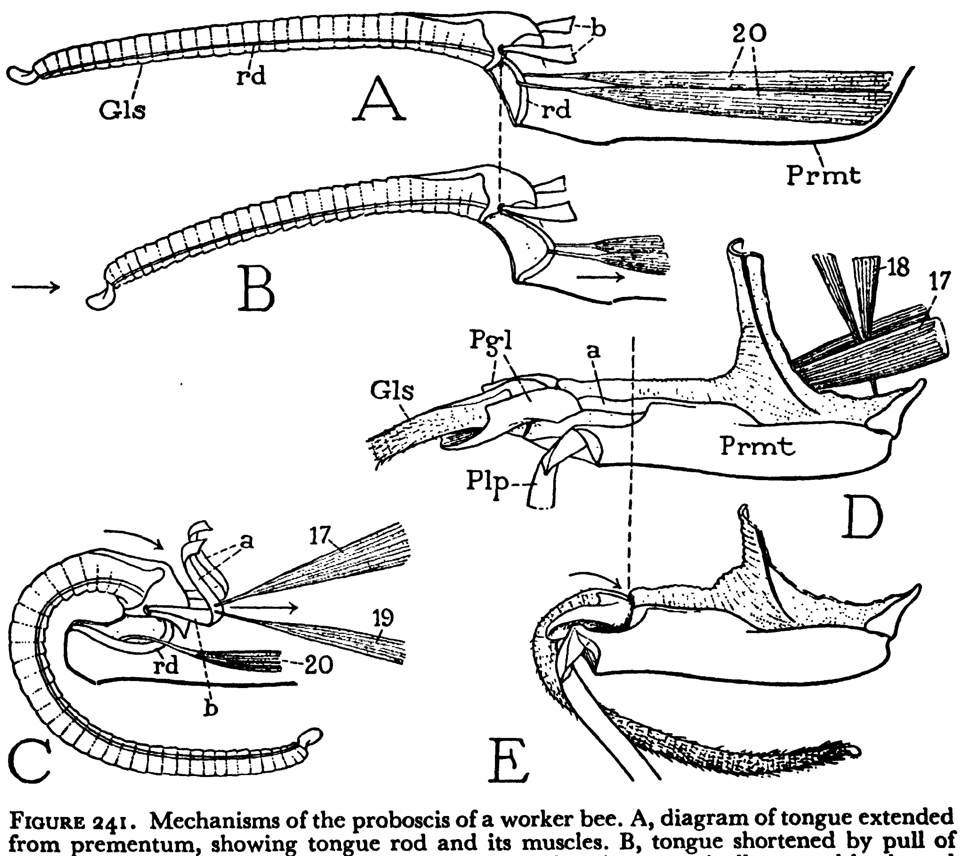



FIGURE 241. Mechanisms of the proboscis of a worker bee. A, diagram of tongue extended from prementum, showing tongue rod and its muscles. B, tongue shortened by pull of muscles on base of tongue rod. C, tongue retracted and automatically curved backward by pull of muscles (*17, 19*) attached on supporting arms (*a*) of tongue base. D, base of labium, with tongue and paraglossae extended. E, same with tongue and paraglossae retracted and tongue curved back as at C.
*a*, supporting arms of tongue and paraglossae; *b*, pivotal supports of tongue; *Gls*, tongue; *Pgl*, paraglossae; *Plp*, labial palpus; *Prmt*, prementum; *rd*, flexible rod of tongue; *17, 19*, retractor muscles of tongue and paraglossae; *18*, adductor muscle of labium; *20*, muscles of tongue rod. (*Drawing courtesy Bureau of Entomology and Plant Quarantine*)

*(Ephy)*, projecting from beneath the labrum *(Lm)*. The lower lip of the mouth is extended in a broad, two-pointed, biblike fold (*bib*) that hangs down against the labial floor of the food channel (Fig. 242, A, *bib*). In the functional feeding position the base of the proboscis is drawn up against the mouth (Fig. 240, C), by which act the food channel (B, *FC*) is outwardly closed by the appression of two cushionlike lobes on the maxillae (*lcl*) against the epipharynx (*C, Ephy*). There thus is established a continuously closed passageway from the tip of the proboscis to the mouth, through which the liquid food is drawn up to the latter. The sucking apparatus, however, is contained within the head.

When, after feeding, the proboscis is drawn up and folded behind the head (Fig. 240, H), the tongue appears to be much shorter than before. Its decrease in length is due partly to the contraction of its rings, but it may be noted (Fig. 241, E), by comparison with the extended position (D), that the bases of the tongue and paraglossae (*Pgl*) have been deeply retracted into the end of the prementum. The muscles that retract the proboscis are a pair of long labial muscles (D, *17*) arising on the top of the head and inserted on the distal ends of the premental bars (C, *a*) along with another pair of muscles (*19*) arising in the prementum. When these muscles contract they bend the premental bars sharply inward (C), and the bars bring with them the attached bases of the tongue and paraglossae. The tongue rod (*rd*), however, is thus pulled so far out of the base of the tongue that its tension automatically curves the tongue backward beneath the prementum. Since there is no mechanism for extending the retracted parts, the reverse action probably results either from the elasticity of the flexed bars or from blood pressure caused by drawing the base of the proboscis close against the head. The flexing of the labial palpi and the maxillary galeae is produced by specific flexor muscles attached on the bases of these appendages.

## The Sucking Pump

The active sucking apparatus is a large, sacklike expansion of the alimentary tract within the head (Fig. 240, F, *Pmp*) extending from the mouth to the neck foramen. At its upper end the sack contracts into a narrow tube, the oesophagus (*Oe*), that runs back through the neck and the thorax (Fig. 251, A) into the abdomen, where it enlarges to form the crop or honey stomach (*HS*). The walls of the pump sack are strengthened by a rod on each side (Fig. 240, F, *y*) running obliquely upward from a plate on the floor of the mouth, and are covered mostly by circular and lengthwise muscle fibers that probably cause a bulblike expansion and contraction of the sack. On the lower part of the anterior wall, however, are attached five pair of thick bundles of dilator muscle fibers *(dlmcl)* arising on the clypeal plate of the head *(Clp)*, and between these muscles (not shown in the diagrammatic figure) are strong compressor muscles running obliquely crosswise against the wall of the sack. This

region of the sack, therefore, which lies just within the mouth is the true *pump* of the sucking apparatus. Liquids are drawn into the sack through the mouth by the action of the dilator muscles; contraction of the compressor muscles then closes the mouth and drives the liquid into the upper part of the muscular sack, which in turn forces it into the narrow oesophagus. Inasmuch as regurgitation of nectar and honey is an important function of the bee's feeding apparatus, it is probable that the pump is used for both ingestion and egestion of food.

## The Salivary System

Between the root of the tongue and the distal end of the labial prementum anteriorly is a deep depression (Fig. 240, E, *SlO*), mostly concealed by the overlapping paraglossae (*Pgl*). At the bottom of this depression is an opening that leads into a small pocket of the prementum (F, *Syr*). By exposing the pocket, it is seen that its walls are provided with dilator and compressor muscles, and that into its inner end opens the common duct of the salivary glands (*SlD*). This apparatus is a pump for the ejection of the saliva and may be termed the *salivary syringe.*

The saliva is secreted by two pair of glands discharging finally into one median duct. The glands of one pair lie in the back of the head,

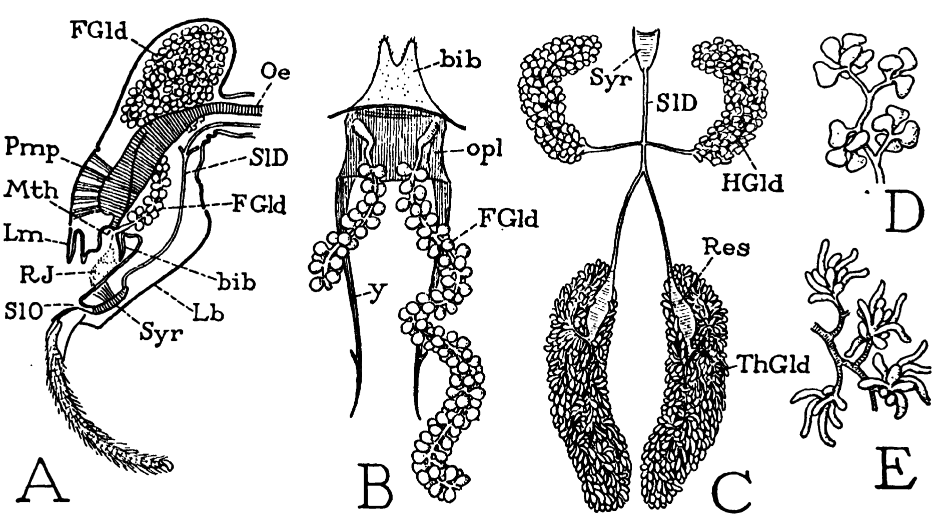



Figure 242. Glands of the head and thorax of a worker bee. A, vertical section of head showing food gland (*FGld*) of right side. B, under surface of oral plate, showing openings of food glands. C, general view of the salivary system, including head glands (*HGld*), thoracic glands (*ThGld*), ducts, and salivary syringe (*Syr*). D, detail of head gland. E, detail of thoracic gland.

*bib*, biblike fold from lower lip of mouth; *FGld*, food gland; *HGld*, head salivary gland; *Lb*, labium; *Lm*, labrum; *Mth*, mouth; *Oe*, oesophagus; *opl*, oral plate on floor of mouth; *Pmp*, sucking pump; *Res*, reservoir of thoracic gland; *RJ*, royal jelly; *SlD*, salivary duct; *SlO*, orifice of salivary duct; *Syr*, salivary syringe; *ThGld*, thoracic salivary gland; *y*, arm of oral plate. (*Drawing courtesy Bureau of Entomology and Plant Quarantine*)

those of the other pair in the ventral part of the thorax. The *thoracic glands* (Fig 242, C, *ThGld*) consist of masses of elongate or tubular saccules at the ends of branching ducts (E) that lead into a pair of reservoir sacks (C, *Res*). From the reservoirs two ducts go forward and unite just behind the head in the common median duct (*SlD*) that enters the neck foramen of the head and empties into the salivary syringe (*Syr*). The *head glands* (C, *HGld*) are flat masses of small pear-shaped bodies (D) spread over the posterior head wall. Their ducts unite within the head with the common duct from the thoracic glands. The thoracic glands are developed from the silk glands of the larva, and correspond with the usual salivary glands of other insects; the head glands are developed in the pupa as outgrowths from the common salivary duct.

From the salivary syringe the saliva is ejected into the cavity on the labium at the root of the tongue, but it is here confined by the overlapping paraglossae (Fig. 240, E, *Pgl*), and within the latter is conveyed around the base of the tongue into the channellike groove on the posterior or undersurface of the tongue (A, D, *sc*). Through this channel probably it is conducted to the tip of the tongue where it flows out over the smooth undersurface of the flabellum (A, *Fbl*) to mix with the nectar or honey being drawn into the proboscis, or is used as a solvent if the bee is feeding on sugar.

### The Brood-Food Glands

The glands that produce the food material called "royal jelly," which the workers feed to the queen, drones, and larvae, are two long strings of small saccules (Fig. 242, A, *FGld*) closely packed in many loops and coils in the sides of the head. The axial ducts of these food glands open separately by two small pores on the outer lateral angles of a broad plate on the floor of the mouth (B, *opl*). From the inner angles of the plate, as already noted, a pair of rods (y) extends upward in the lateral walls of the sucking pump (Fig. 240, F, *y*); on the end of each rod are attached two opposing muscles from the head wall. It would appear, therefore, that the mouth plate is movable by means of its muscles and probably has some function in discharging the royal jelly from the mouth. The food evidently must run down the biblike flap that hangs from the lower lip of the mouth (Fig. 242, A, *bib*) and accumulate (*RJ*) in the food channel on the base of the proboscis. The open channel thus serves as a feeding trough for other adult bees. The feeding bees obtain the royal jelly by thrusting the end of the proboscis over the base of the tongue of the feeder bee, the proboscis of the latter being turned back, the mandibles opened, and the labrum raised. When the nurses feed the larvae, however, the royal jelly is said to be discharged from between the partly opened mandibles into the bases of the brood cells of the comb for young larvae; but when the larvae fill the bases of the cells, then on the exposed outer part of the individual larvae.

## The Thorax, The Legs, and The Wings

The thorax of an insect is the middle division of the trunk which carries the legs and the wings. Its cavity is largely occupied by the muscles of the locomotor appendages and the muscles that move the head and the abdomen, the other internal organs being mostly contained in the head and the abdomen (Fig. 251, A). The nerve centers of the thorax, however, are particularly large (Fig. 254) because they control the activities of the thoracic muscles.

### Structure of the Bee's Thorax

The thorax of the bee and related Hymenoptera, as already noted, consists of four body segments which, beginning with the first, are designated the *prothorax* (Fig. 238, 1), the *mesothorax* (*2*), the *metathorax* (*3*), and the *propodeum* (I), but the several segments are so closely united that it is difficult to observe their limits. In studying a thoracic segment we distinguish a back plate or *notum,* a ventral plate or *sternum,* and a plate or group of plates on each side called the *pleuron.*

The prothorax of the bee is merged with the neck to form a slender support for the head, and carries the first pair of legs. Its back plate, the

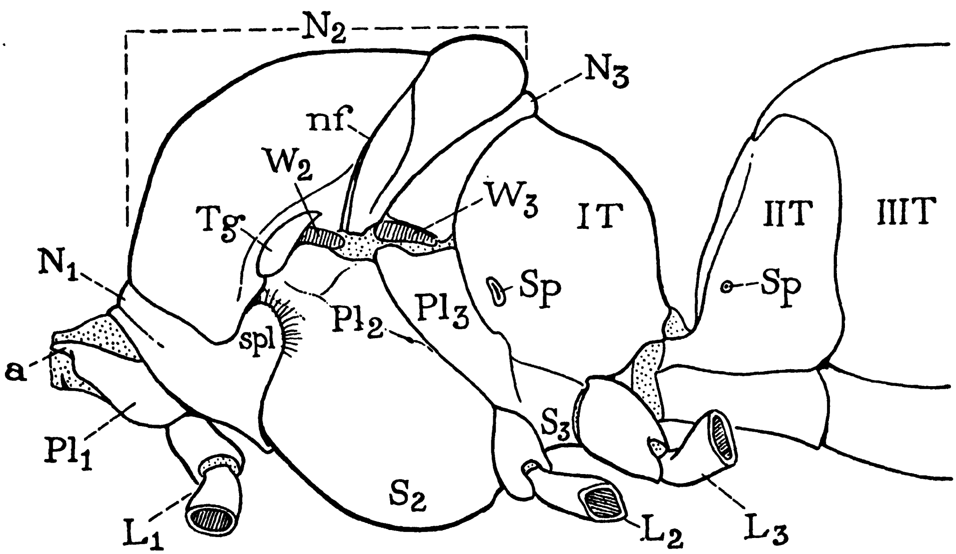



FIGURE 243. The thorax and base of the abdomen, left side, of a worker bee. *a,* pivotal point supporting head; *I T,* back plate of propodeum; *II T, III T,* back plates (terga) of first and second abdominal segments; $L_1$, $L_2$, $L_3$, bases of legs; $N_1$, pronotum; $N_2$, mesonotum; $N_3$, metanotum; *nf,* notal fissure; $Pl_1$, pleuron of prothorax; $Pl_2$, pleuron of mesothorax; $Pl_3$, pleuron of metathorax; $S_2$, $S_3$, sternal areas of mesothorax and metathorax; *Sp,* spiracle; *spl,* lobe of pronotum covering first spiracle; *Tg,* tegula; $W_2$, $W_3$, bases of wings. (*Drawing courtesy Bureau of Entomology and Plant Quarantine*)

*pronotum* (Fig. 243, $N_1$), is set like a collar on the front of the mesothorax, and is expanded on each side in a flat lobe (*spl*) that covers the first pair of breathing apertures. The pleural and sternal plates of the prothorax support the first legs ($L_1$), and the head is pivoted on a pair of peglike processes (*a*) projecting from the anterior ends of the pleura. The mesothorax is the largest part of the thorax. The mesonotum ($N_2$) lies above the wing bases ($W_2$) forming the uppermost bulge of the thoracic wall and sloping steeply downward to the pronotal collar. Below the wings the pleural and sternal walls of the segment ($Pl_2$, $S_2$) are continuous from one side to the other. The metathorax is a narrow band angularly bent forward on the sides, closely wedged between the mesothorax and the propodeum. The metanotum ($N_3$) widens somewhat toward the wing bases ($W_3$); the pleural plates ($Pl_3$) are continuous with the sternum ($S_3$) as in the mesothorax. The fourth thoracic segment, or propodeum, consists mostly of a large back plate (*IT*) firmly united with the metathorax. It has no pleural elements and its sternum is a weak ventral plate behind the third legs. Posteriorly the propodeum is abruptly narrowed to give attachment to the abdominal petiole. Further details of the thoracic structure will be described in connection with the wings and their mechanism.

## The Legs of the Bee

The three pair of legs of an insect are seldom alike in size or shape, but each is divided into six principal parts or *segments,* movable on each other at flexible *joints* (Fig. 244, A). The basal leg segment is the *coxa* (*Cx*); the second segment is the *trochanter* (*Tr*); the third, usually a long segment, is the *femur* (*Fm*); the fourth is the *tibia* (*Tb*), the fifth is the *tarsus* (*Tar*); and the last is the *pretarsus* (*Ptar*). The tarsus, however, is subdivided into several small parts or *tarsomeres.* The pretarsus is a very small segment but it carries a pair of lateral *claws* (E, *Cl*) and a median lobe termed the *arolium* (*Ar*).

The joints between the leg segments are mostly hinges with motion limited to one plane, no part of an insect's leg having anything like the freedom of movement at the joints of a vertebrate limb as the human arm. As a consequence the insect has little choice as to what it can do with its legs, and hence all individuals of a species do the same things in practically the same way. The limitation of action at the joints is partly compensated by the number of segments that move in different directions.

Each leg of the bee is hinged to the body on an obliquely transverse axis and therefore swings as a whole only forward and backward. At the first leg joint, that between the coxa and the trochanter (Fig. 244, A), the part of the leg beyond the coxa turns up and down in a plane at right angles to the plane of movement of the entire leg on the body. The muscles of the trochanter hence raise and lower the leg at the coxotrochanteral joint; but if the feet are against a support the contraction

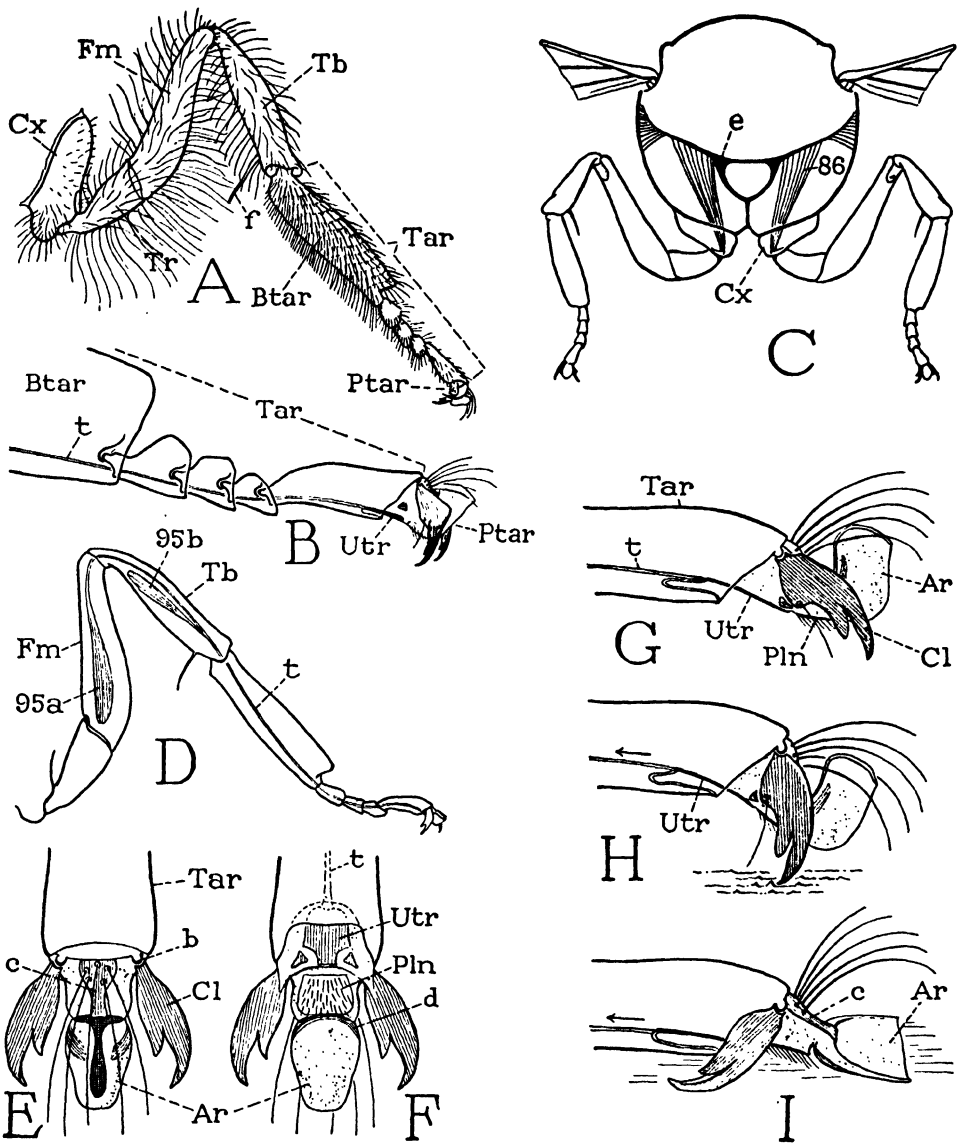



FIGURE 244. General structure of the legs of a worker bee. A, middle leg of worker. B, tarsus and foot (pretarsus) more enlarged. C, cross section of mesothorax, with middle legs. D, outline of middle leg, showing muscles and tendon of pretarsus. E, pretarsus, upper surface. F, same, lower surface. G, diagram of foot (pretarsus) with claws extended. H, same, with claws grasping a rough surface. I, same, arolium spread out on a smooth surface on which claws fail to hold.

*Ar*, arolium; *b*, articular knob of claw; *Btar*, basitarsus; *c*, handle-like bar of arolium braced on end of tarsus; *Cl*, claw; *Cx*, coxa; *d*, elastic band in under wall of arolium; *e*, internal framework of thorax; *f*, spine of tibia; *Fm*, femur; *Pln*, planta; *Ptar*, pretarsus (foot); *t*, tendon of pretarsal muscles; *Tar*, tarsus; *Tb*, tibia; *Tr*, trochanter; *Utr*, unguitractor plate. (*Drawing courtesy Bureau of Entomology and Plant Quarantine*)

of the depressor muscles lifts the body on the legs. The trochanter has several small muscles arising in the coxa, but, to increase the lifting power, each trochanter is provided with a long muscle arising on an internal framework within the thorax (Fig. 244, C, *86*). The trochanter is joined to the femur by an oblique hinge in a vertical plane which thus does not interfere with the lifting power of the trochanteral muscles, though it gives only a slight backward bend to the femur. The articulation between the femur and the tibia is a typical knee joint, at which the tibia can be extended or flexed on the end of the femur by long extensor and flexor muscles arising in the femur.

The tarsus of the bee (Fig. 244, A, B, *Tar*) consists of five parts, or tarsomeres, of which the first is much longer and thicker than the others in all the legs, and is distinguished as the *basitarsus* (*Btar*). The large, flat basal subsegment of the hind tarsus (Fig. 245, C, *Btar*) is commonly called the "planta" by writers on the honey bee, but the word *planta* in Latin means "the sole of the foot," and the term is so used in general zoology. In insects the planta is properly a small ventral sclerite of the pretarsus (Fig. 244, F, *Pln*). The tibiotarsal joint differs from the other leg joints in that it allows more freedom of movement to the tarsus, which has three muscles attached on the basitarsus that give three separate movements. The large basitarsus is followed by three very small tarsomeres, and the fifth longer tarsomere carries at its extremity the pretarsus (*Ptar*). Between the subsegments of the tarsus (B) there are no muscles, the tarsomeres being flexible on each other but having no power of individual movement. The entire tarsus, however, is traversed by the tendon (B, *t*) of the pretarsal muscles arising in the femur and the tibia (D, *95a*, *95b*).

The pretarsus, which might be termed the "foot" of the insect, is a very important part of the leg since it bears the organs by which the insect clings to supporting surfaces. The pretarsal claws (Fig. 244, E, F, *Cl*) maintain a hold on rough surfaces; the arolium (*Ar*) adheres to smooth surfaces. The claws of the bee are double pointed and their deep bases are implanted vertically in the lateral walls of the pretarsus, but each claw is articulated to a small knob (E, *b*) on the end of the tarsus. The arolium projects from the end of the pretarsus between the claws. When not in use (G, H) it is turned upward and appears to be merely a soft, oval lobe, though closer inspection shows that it is deeply concave on its upper or anterior surface (E), that is, its sides are folded together upward. The basal lip of the aroliar cavity is braced against the end of the tarsus by a bottle-shaped sclerite (*c*) on the upper wall of the pretarsus bearing five or six long curved bristles. The arolium thus resembles a scoop with a long handle. Its convex outer wall contains a U-shaped elastic band (F, *d*).

In the lower wall of the pretarsus (Fig. 244, F) are two median plates; the stronger proximal one, which is partly concealed in a pocket at the end of the tarsus, is the *unguitractor plate* (*Utr*); and the distal one,

covered with strong spines, is the *planta* (*Pln*). The concealed proximal end of the unguitractor plate is connected with the end of a strong internal tendon (*t*) that runs through the entire tarsus (D) into the tibia where it divides into two branches; one branch gives attachment to a muscle in the tibia (95b), and the other goes on into the femur and ends in a long muscle arising in the base of the femur (95*a*). These muscles operate both the claws and the arolium by their pull on the tendon and the attached unguitractor plate.

The mechanism of the foot structure is illustrated diagrammatically at G, H, and I of Fig. 244. At G the claws are extended and the arolium (*Ar*) turned upward in the usual position. At H the unguitractor plate (*Utr*) has been retracted by its muscles into the end of the tarsus, and, as the plate is closely associated with the bases of the claws, the claws are flexed until irregularities of the surface of contact restrain their points. In this way the bee is enabled to cling to rough surfaces. At I the bee is supposed to be resting on a smooth surface on which the claws have not been able to hold; the continued pull of the muscles, therefore, has turned the claws so far forward that they sprawl out helplessly with their points upward. But now the traction of the unguitractor plate is exerted on the planta and finally on the base of the arolium. The aroliar handle (*c*), however, being braced against the tarsus, prevents a retraction of the arolium, but the tension and pressure on the base of the arolium, together with the pressure of the leg against the support, flatten the aroliar scoop to the form of a dustpan. The broad, soft undersurface of the spread-out arolium now adheres to the smooth surface which the claws failed to grasp. It has been said that the adhesive property of the arolium is due to a sticky liquid exuded from the spines of the planta. On release of the muscle pull on the unguitractor plate, the elastic band in the under wall of the arolium causes the latter to fold up again, and the claws, by the elasticity of their basal connections, are once more extended.

Though the legs are primarily organs of locomotion, various specialized parts of the legs of the honey bee serve for purposes other than that of walking or running. The brushes of stiff hairs on the inner surfaces of the long basal segments of the anterior tarsi (Fig. 245, I, g) are used for cleaning pollen or other particles from the head, the eyes, and the mouth parts. Similarly the bushy middle tarsi (Fig. 244, A) serve as brushes for cleaning the thorax. The long spines at the ends of the middle tibiae (*f*) are said to be used for loosening the pellets of pollen from the pollen baskets of the hind legs, and also for cleaning the wings and the spiracles. The wax scales are removed from the wax pockets of the abdomen by means of the legs, but there is some difference of opinion as to just how it is done. The special structures of chief interest on the legs, however, are the antenna cleaners on the forelegs of all castes, and the pollen-collecting and pollen-carrying apparatus on the hind legs of worker bees.

## The Antenna Cleaner

The structures used by the bee for cleaning its antennae are situated on the inner margins of the forelegs just beyond the tibiotarsal joints (Fig. 245, I, *h*). Each antenna cleaner consists of a deep semicircular notch on the basal part of the long basitarsus (A, *i*), and of a small clasp-like lobe (*j*) that projects over the notch from the end of the tibia. The margin of the notch is fringed with a comblike row of small spines. The clasp is a flattened appendage, tapering to a point and provided with a small lobule (*k*) on its anterior surface; it is flexible at its base but has no muscles. As this gadget is used by the bee, the open tarsal notch is first placed against the antennal flagellum by appropriate movements of the leg; then by flexing the tarsus against the tibia (B), the flagellum is brought against the tibial clasp which resists the pressure because of a small stop-point (*l*) behind its base. The flagellum, thus held in the notch by the clasp, is now drawn upward between the comb of the notch and the scraping edge of the clasp. The antenna cleaner is present in the queen and the drone as well as in the worker.

## The Pollen-Collecting Apparatus and the Pollen Baskets

The hind legs differ from the other legs in their large size and the broad, flattened form of the tibia and basitarsus (Fig. 245, C), which latter parts differ also as between the worker (C), the queen, and the drone (H). It is only in the worker that there is any evident reason for the special shape of the hind legs. The smooth, somewhat concave, outer surface of the hind tibia of the worker is fringed with long, curved hairs (D), and the space thus enclosed is the so-called *pollen basket* or *corbicula* (*cbl*) in which pollen (also propolis) is carried to the hive. The pollen stored in the baskets is first collected from the body by the fore and middle legs and deposited on the large flat brushes on the inner surfaces of the broad basal segments of the hind tarsi, each of which is covered with about ten transverse rows of stiff spines projecting posteriorly (C, *Btar*). The apparatus for transfer of the pollen from the brushes to the baskets are the deep notches in the upper margins of the legs between the tibiae and the tarsi (*pr*). The tibial margin of each notch is armed with a *rake* of short, stiff spines (E, *r*); the opposing tarsal margin is flattened transversely and extended laterally into a small triangular lip, or *auricle* (*au*), fringed with hairs.

The transfer of the pollen from the collecting brushes to the baskets is accomplished as follows: When the basitarsal brushes are sufficiently loaded with pollen, the leg of one side is rubbed against the other in such a manner that the rake on the end of the tibia scrapes off a small mass of pollen from the tarsal brush of the opposite leg. The detached pollen grains fall on the flat surface of the auricle which is beveled upward and outward. Consequently, when now the tarsus is closed against

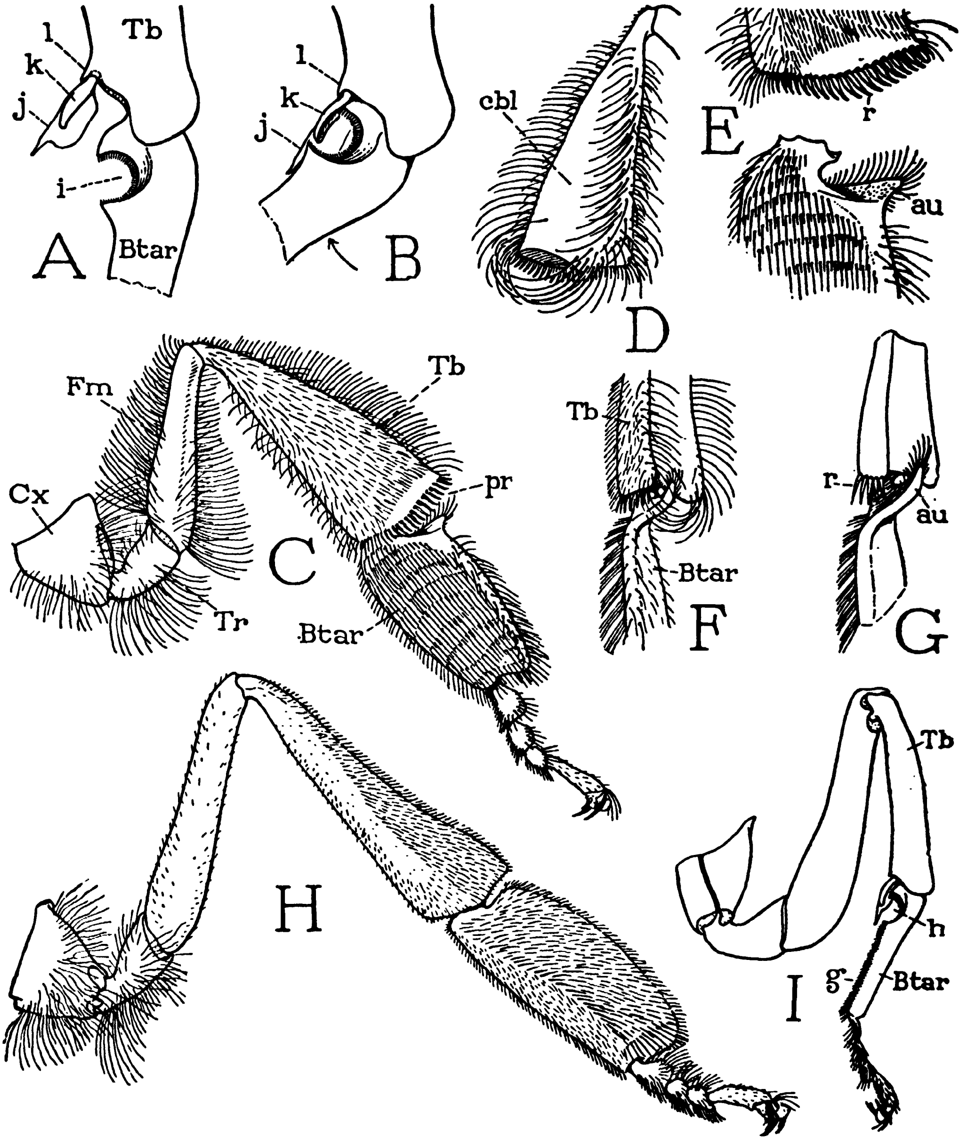



FIGURE 245. Special features of the legs of a worker bee (except H). A, antenna cleaner of first leg, open. B, same, closed. C, hind leg of worker, inner surface, showing pollen collecting brush on basitarsus (*Btar*) and pollen press (*pr*). D, pollen-basket (corbicula) on outer surface of hind tibia (C, *Tb*). E, end of hind tibia with pollen rake (*r*) and opposing end of basitarsus with auricle (*au*). F, pollen press between tibia and basitarsus, dorsal view. G, same, better seen after removal of tibial hairs. H, hind leg of drone. I, first leg of worker, showing position of antenna cleaner.
*au*, auricle; *Btar*, basitarsus; *cbl*, pollen basket; *Cx*, coxa; *Fm*, femur; *g*, tarsal brush of first leg; *h*, antenna cleaner; *i*, notch of antenna cleaner; *j*, clasp of antenna cleaner; *k*, lobe of clasp; *l*, stop-point for clasp; *pr*, pollen press; *r*, pollen rake; *Tb*, tibia. (*Drawing courtesy Bureau of Entomology and Plant Quarantine*)

the tibia (Fig. 245, F, G), the pollen on the auricle is forced upward and pressed outward against the outer surface of the tibia where, being wet and sticky, it adheres to the floor of the pollen basket. A repetition of this process, first on one side, then on the other, successively packs more and more pollen into the lower ends of the baskets, until finally both are filled.

The pollen baskets are used also for the transport of propolis, but the pollen presses play no part in loading the baskets in this case. Propolis is a resinous gum collected by bees with their mandibles from trees or other plants. The resin particles, it is said, are gathered up with the fore and middle legs and placed directly in the baskets of the hind legs.

## The Wings of the Bee

The wings of an insect are flat, thin, two-layered extensions of the body wall, strengthened by tubular thickenings called *veins*. They arise from the sides of the mesothorax and the metathorax between the notal and pleural plates of these segments. In the honey bee the fore wings (Fig. 246, A) are much larger than the hind wings (B) and their venation is stronger, but the two wings of each side work together in flight. To insure unity of action the wings are provided with a coupling apparatus formed by a series of upturned hooks on the front margin of each hind wing (B, *h*), and a decurved fold on the rear margin of the fore wing (A, *f*). When the wings are extended preparatory to flight, the fore wings are drawn over the hind wings, and the hooks of the latter automatically catch in the marginal folds of the former (E).

Each wing is hinged by its narrowed base to the margin of the back plate of its segment, and is supported from below on the upper edge of the corresponding pleuron. The wings are thus free to move up and down; but progressive flight requires other movements, including a forward and backward motion of each wing, and a twisting or partial rotation of the wing on its long axis. These latter components of the flight movement depend on details of structure in the wing bases. All the wing movements, except such as may result from air pressure during flight, are produced by thoracic muscles; but most of the muscles involved are attached not on the wings themselves, but on movable parts of the thorax that indirectly affect the wings. Hence, for an understanding of the flight mechanism, we shall have to make a further study of the thoracic structure. Moreover, the wings when not in active use are folded horizontally backward over the abdomen. From this position of rest they can quickly be extended to the position of activity. In addition to the flight mechanism, therefore, we must distinguish a mechanism of *flexion* and *extension* for each wing individually. It will be logical to give attention first to the structures that produce these horizontal movements.

If the base of one of the wings, a fore wing for example (Fig. 247, A), is spread out flat it will be seen that it contains several small plates or

*axillaries.* Two of the axillaries, the *first* (*1Ax*) and the *fourth* (*4Ax*), are the hinge plates by which the wing articulates on the edge of the notum. Another, the *second axillary* (*2Ax*) lying behind the first, rests on the upper edge of the pleuron (B, $Pl_2$) and constitutes the pivotal plate of the wing base. A third long sclerite (A, *3Ax*) extends outward along the thickened margin of the basal wing membrane, and this axillary is the skeletal element of the flexing mechanism. On its proximal part are attached three small muscles (F) arising on the pleuron. These muscles in contraction lift the outer end of the third axillary and revolve it toward the back, producing necessarily a fold in the wing base which causes the extended wing to turn horizontally backward. The flexor action of the third axillary can be well illustrated with a piece of paper cut and creased as at D of Fig. 247. By lifting the point *d* at the outer end of the "axillary" (*3Ax*) and revolving it upward to the left (*E*), the base of the "wing" turns with it along the line *bc;* and the distal part folds horizontally backward along the line *ab,* as the triangle *abc* turns over.

The extension of the flexed wing is caused by the movement of a small sclerite resting on the pleuron beneath the front part of the wing

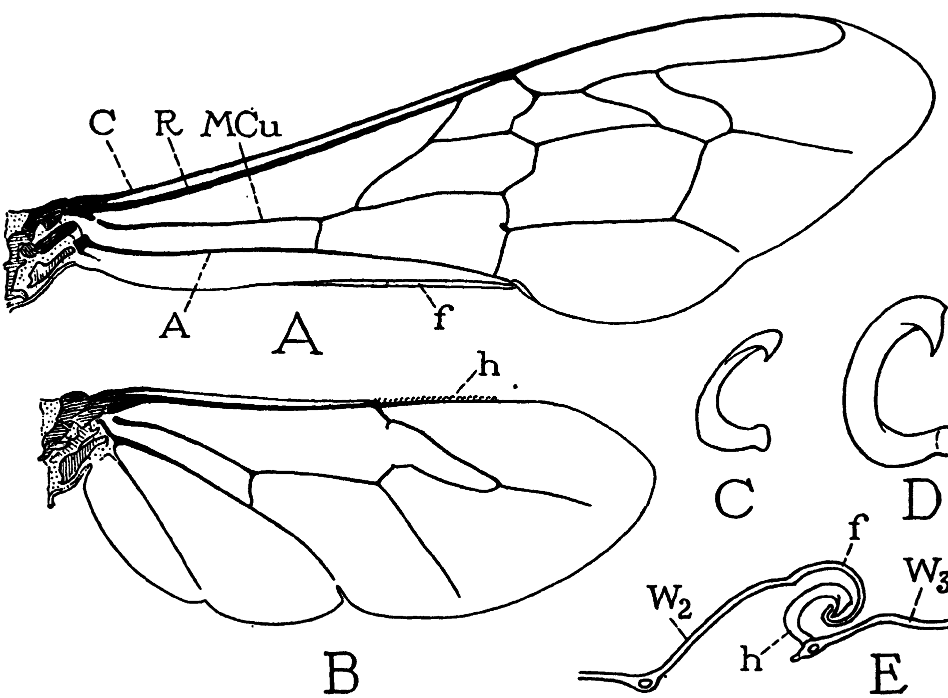



FIGURE 246. The wings of a worker bee. A, right fore wing of worker. B, right hind wing. C, hind wing hook of worker. D, wing hook of drone. E, section of fore and hind wings showing interlocking by fold and hooks.
*A*, anal vein; *C*, costal vein; *f*, marginal fold of fore wing; *h*, marginal hooks of hind wing; *R*, radial vein; *MCu*, median and cubital veins united; $W_2$, fore wing; $W_3$, hind wing. (*Drawing courtesy Bureau of Entomology and Plant Quarantine*)

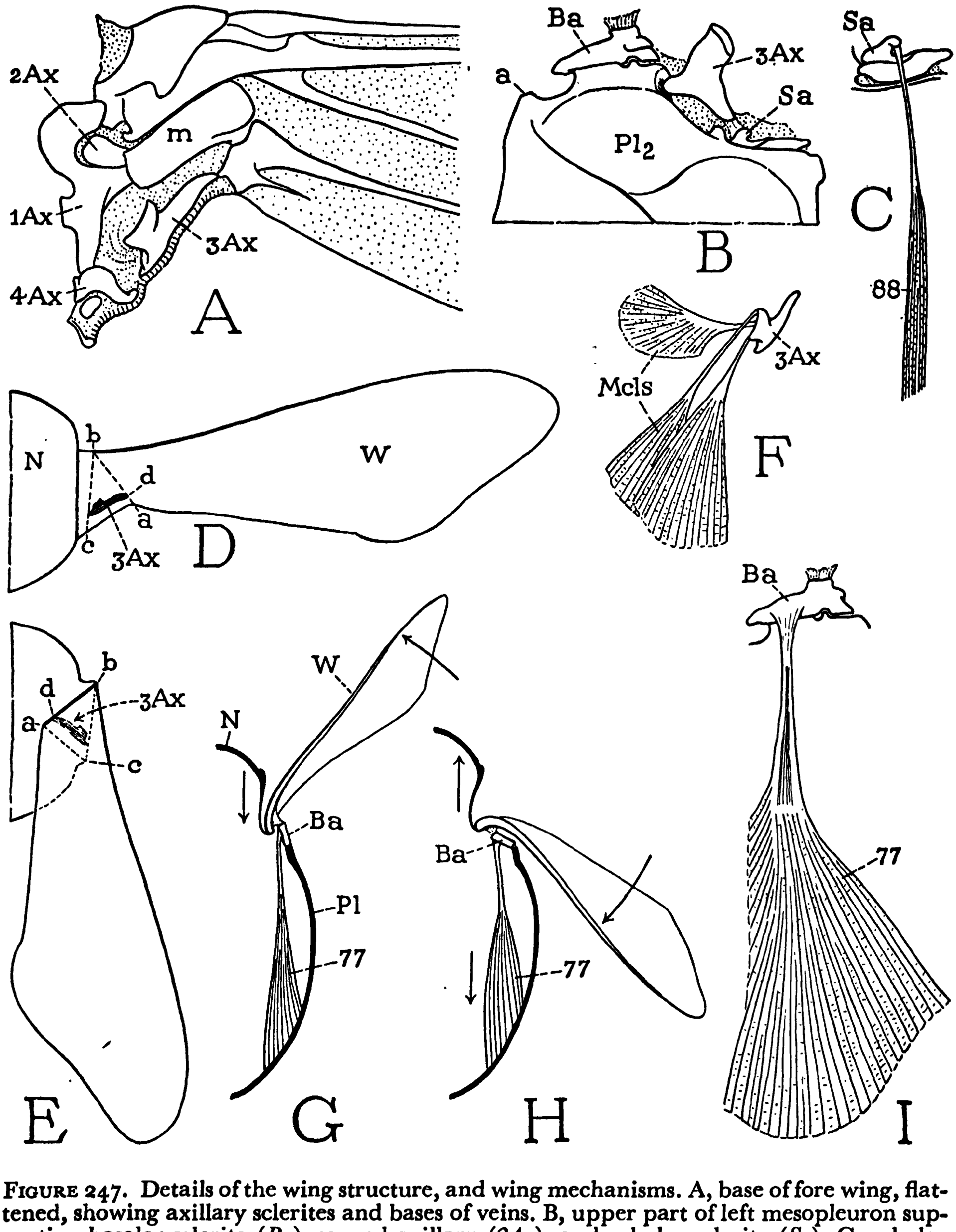



FIGURE 247. Details of the wing structure, and wing mechanisms. A, base of fore wing, flattened, showing axillary sclerites and bases of veins. B, upper part of left mesopleuron supporting basalar sclerite (*Ba*), second axillary (*2Ax*), and subalar sclerite (*Sa*). C, subalar sclerite and its muscle. D, diagram of extended wing and lines of folding in base. E, diagram of wing turned horizontally over back. F, third axillary (flexor sclerite) of fore wing and its muscles. G, diagram of raised wing with front margin elevated. H, same, wing lowered, front margin depressed by contraction of basalar muscle (77). I, basalar sclerite of fore wing and its muscle.

*a-b, b-c,* lines of folding in wing base; *1Ax, 2Ax, 3Ax, 4Ax,* first, second, third, and fourth axillary; *Ba,* basalar sclerite; *d,* outer end of third axillary; *m,* median plate of wing base; *Mcls,* muscles; *N,* notum; *Pl,* pleuron; *Sa,* subalar sclerite; *W,* wing. (*Drawing courtesy Bureau of Entomology and Plant Quarantine*)

(Fig. 247, B, *Ba*) and connected with the latter by a tough membrane. On this sclerite, called the *basalare,* is attached a long muscle (G, I, 77) from the lower part of the pleuron, which by contracting turns the basalare inward on the pleuron (H, *Ba*), and thus pulls indirectly on the wing base before the pivotal second axillary, with the result that the wing is swung forward on the latter. The action is easily demonstrated by pressing the point of a needle against the basalare.

The flight movements of the wing, as already stated, are compound. They include an up-and-down component, a forward-and-backward component, and a torsion, or partial rotary movement of the wing on its long axis. The up-and-down strokes are caused by vibrations of the back plate of the wing-bearing segment. Because the two wings of a segment are supported from below on the pleura, a depression of the back plate causes the wings, in the manner of a pump handle, to go up (Fig. 248, A), as can be demonstrated by pressing downward on the back of a bee. A reverse movement of the back (B) depresses the wings. The major part of the wing mechanism is that which produces the vibrations of the back plates.

If the thorax of a bee is cut open (Fig. 248, D, E) it will be seen that it is almost filled with great masses of muscle fibers. In each side of the mesothorax is a thick column of vertical fibers (72) attached dorsally on the notum, and another smaller muscle (E, 75) is attached on the margin of the notum. These muscles are the depressors of the back and, therefore, the *elevator muscles of the wings* (A). Between the first pair are two flat bundles of fibers (D, E, *71*) running obliquely lengthwise from the median area of the mesonotum to a strong, internal U-shaped band, the *second phragma* (D, *2Ph*), extending from the mesonotum far back into the propodeum. These are the *depressor muscles of the wings* because their contraction compresses the mesonotum in a lengthwise direction, and hence elevates the back, causing the wings to turn downward (B). It will be recalled that the two wings on each side are hooked together during flight. The mesothorax has wing-elevator muscles of its own, but the downstroke of both pair of wings is produced by the mesothoracic muscles and depends on the coupling of the fore and hind wings with each other.

In most insects the back plates of the wing-bearing segments are sufficiently flexible to respond by vibratory movements to the alternating pull of the vertical and lengthwise muscles attached on them. The mesonotum of the bee, however, is a rigid and strongly convex plate. In order to perform its function in connection with the wings it is cut by a deep, crosswise groove (Fig. 248, D, F, *nf*) into a larger anterior plate, (F, $1N_2$) and a smaller posterior plate ($2N_2$). The middle part of the groove on the top of the back acts as a hinge between the two plates; the lateral parts open out into actual clefts (G, *nf*) having the edges united by infolded membranes. The front angles of the anterior notal plate are

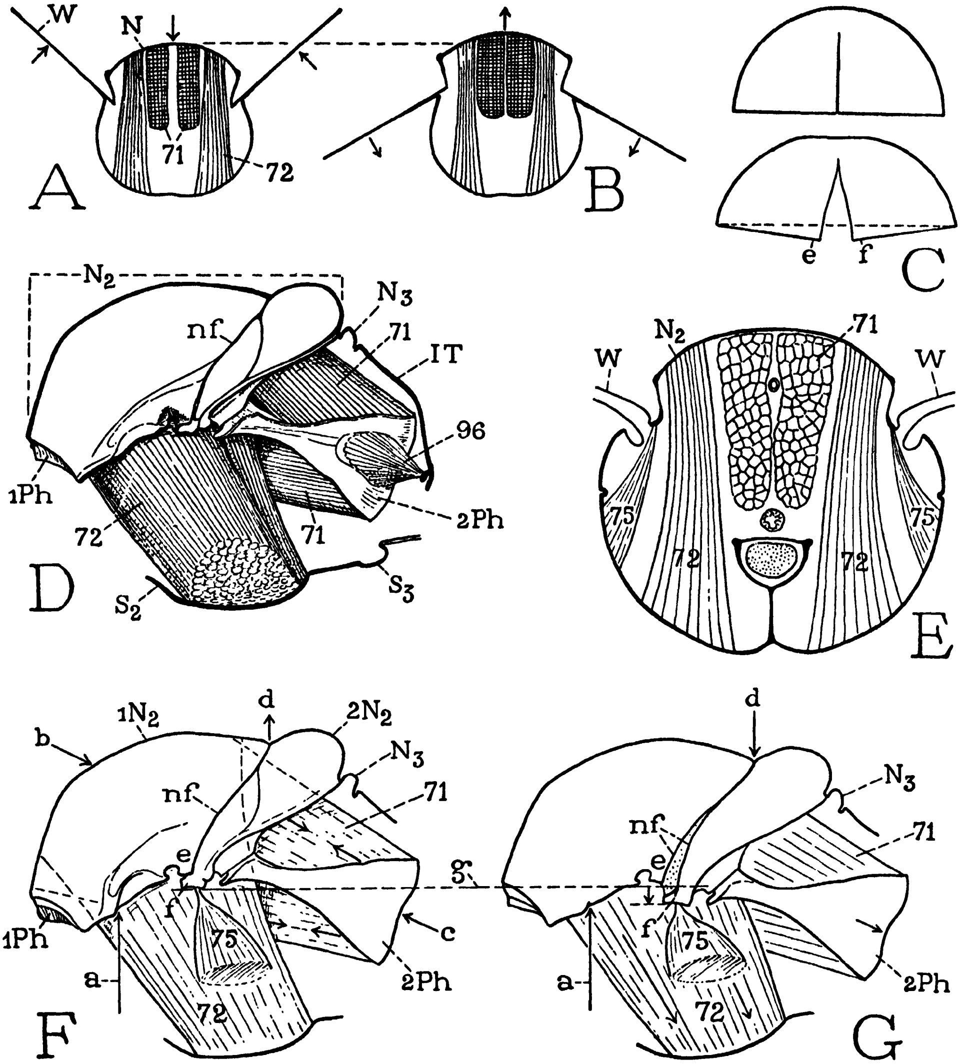



FIGURE 248. The mechanism of the up-and-down movement of the wings. A, cross section of mesothorax with wings elevated. B, same, with wings depressed. C, diagrams of movements of mesonotum that depress and elevate the wings. D, thorax with left wall removed showing muscles. E, cross section of mesothorax through wing bases. F, diagram of position of back plates of mesothorax (*1N*$_2$,*2N*$_2$) when muscle *71* is contracted. G, same when muscles *72* and *75* contract, the notal fissure (*nf*) opened on the side, the marginal points *e* and *f* lowered. (Compare F and G with C.)

*a*, point of support of mesonotum on pleuron; *b-c*, direction of contraction of muscle *71*; *d*, hinge line on back between plates of mesonotum; *e*, *f*, points of greatest movement on margin of mesonotum as notal fissure (*nf*) opens and closes; *g*, horizontal line; *IT*, back plate of propodeum; *N*, *notum*; *N*$_2$, mesonotum, divided by notal fissure (*nf*) into anterior plate (*1N*$_2$) and posterior plate (*2N*$_2$); *N*$_3$, metanotum; *nf*, notal fissure; *1Ph*, first phragma; *2Ph*, second phragma; *S*$_2$, mesosternum; *S*$_3$, metasternum; *W*, wing; *71*, lengthwise muscles of mesothorax (depressors of wings); *72*, *75*, vertical muscles of mesothorax (elevators of wings). (*Drawing courtesy Bureau of Entomology and Plant Quarantine*)

firmly braced on the pleura (as indicated by the arrow at *a*); the posterior notal plate is supported on the metanotum ($N_3$). Contraction of the vertical muscles (G, *72*), therefore, depresses the mesonotum at the hinge line (*d*) on the back and opens the lateral clefts (*nf*) between the two notal plates. Conversely, the contraction of the lengthwise muscles (F, *71*) restores the notum to its original shape by closing the lateral clefts. The opening and closing of the clefts, however, necessarily is accompanied, respectively, by a downward and upward movement of the adjoining tergal margins (*e, f*), as is seen by comparing their positions in F and G relative to the line *g*. The action of the mesonotum may be exactly imitated by compressing half of a hollow rubber ball having a meridional cleft on each side (C). Each wing, being attached to the margin of the back just before and behind the notal cleft, is thus hinged at the points of greatest vertical movement in the notal margin, and it is this movement that causes the up-and-down wing strokes during flight.

A mere flapping of the wings cannot produce flight; the driving force results from a propellerlike twist given to each wing during the upstroke and the downstroke. As the wing descends it goes also somewhat forward and its anterior margin turns downward; during the upstroke the action is reversed. The tip of the vibrating wing, therefore, if the insect is held stationary, describes a figure 8. The mechanism that produces these components of the flight movement includes the basalar sclerite and its muscle (Fig. 247, B, I, *Ba*), already described as causing the extension of the flexed wing; and a similar musculated sclerite (C, *Sa*), designated the *subalare,* resting on the pleural margin beneath the posterior part of the wing base (B, *Sa*). The alternating pull of the basalar and subalar muscles on their respective sclerites not only turns the wings during flight forward and backward, but at the same time deflects their forward margins during the downstroke and reverses the movement during the upstroke. The action of the basalare is illustrated diagrammatically at G and H of Fig. 247. At G the wing is raised by the depression of the notum (*N*), and its rear margin is turned downward by the pull of the subalare (not shown) on the rear part of its base. At H the wing is in the downstroke position caused by the elevation of the notum; but it is also turned forward, with its front margin deflected by the pull of the basalar muscle (*77*) on the basalar plate (*Ba*), which latter in turn pulls downward and forward on the anterior part of the wing base.

The efficiency of the insect flying machine is most surprising, considering the simplicity of the flight mechanism. It is to be observed that the wings not only act as organs of propulsion, but also direct the course of flight as the insect has no other apparatus for steering. Many insects, moreover, can change abruptly the direction of flight without altering the position of the body, going forward, backward, or sideways with equal ease, while finally they can remain stationary, hovering at one point in the air. No airplane yet invented can perform in this manner.

# The Abdomen

The abdomen contains the principal viscera of the insect (Fig. 251, A), such as the stomach, intestine, and reproductive organs, and bears externally the structures concerned with mating and egg laying. Its general outer form is simple as compared with that of the thorax or head (Fig. 238, *Ab*) and its component segments are nearly always distinct.

## The Abdomen of the Bee

The bee larva has ten abdominal segments; but in the adult bee and other related Hymenoptera the abdomen is reduced to nine segments by the transfer, during the pupal stage, of the first larval segment to the thorax. In order to keep the correspondence, or *homology,* of the segments in mind, it is customary to number the segments beginning with the transposed first segment, or propodeum, as segment *I.* The abdomen of the bee, however, is further shortened by a reduction and retraction of some of the posterior segments. Thus in the worker and the queen the abdomen appears to have only six segments (Figs. 238, 249, A), which are segments *II* to *VII,* the tergal and sternal plates of the last forming the conical apex of the body. Segments *VIII, IX,* and *X* are not only concealed within segment *VII,* but they are so reduced in size and altered in form as scarcely to be recognized as segments. In the drone the exposed part of the abdomen ends above with the back plate of segment *VIII,* and below with the sternal plate of segment *IX* (Fig. 255, C). In both sexes the tenth segment is reduced to a small conical lobe (Fig. 249, C, *X*) bearing the anus (*An*); in the female it is entirely concealed in a chamber at the end of the abdomen containing the sting (*Stn*).

Each of the exposed abdominal segments has a large back plate, or *tergum* (Fig. 249, A, G, *T*), and a smaller ventral plate, or *sternum (S).* The successive terga and sterna overlap from before backward, but are connected by infolded *intersegmental membranes.* Likewise the terga overlap the sides of the sterna (G), and the two plates are connected on each side by an infolded lateral membrane. Hence the abdomen is distensible and contractile in both a lengthwise direction (I, J) and a vertical direction (G, H), as may be observed when a bee is breathing strongly.

The mechanism of the abdominal movements is fairly simple. Between the consecutive tergal and sternal plates are stretched long *retractor muscles* (Fig. 249, F, 144, 145, 152, 153) that by contraction (I, *r*) pull the segments together. The opposite movement, or extension of the abdomen, is produced by short *protractor muscles* that arise on projecting lobes of the front margins of the terga and sterna (F, 146, 154), and are attached posteriorly on the overlapping rear margins of the preceding plates. These muscles by contraction (J, *p*) shorten the overlap of the

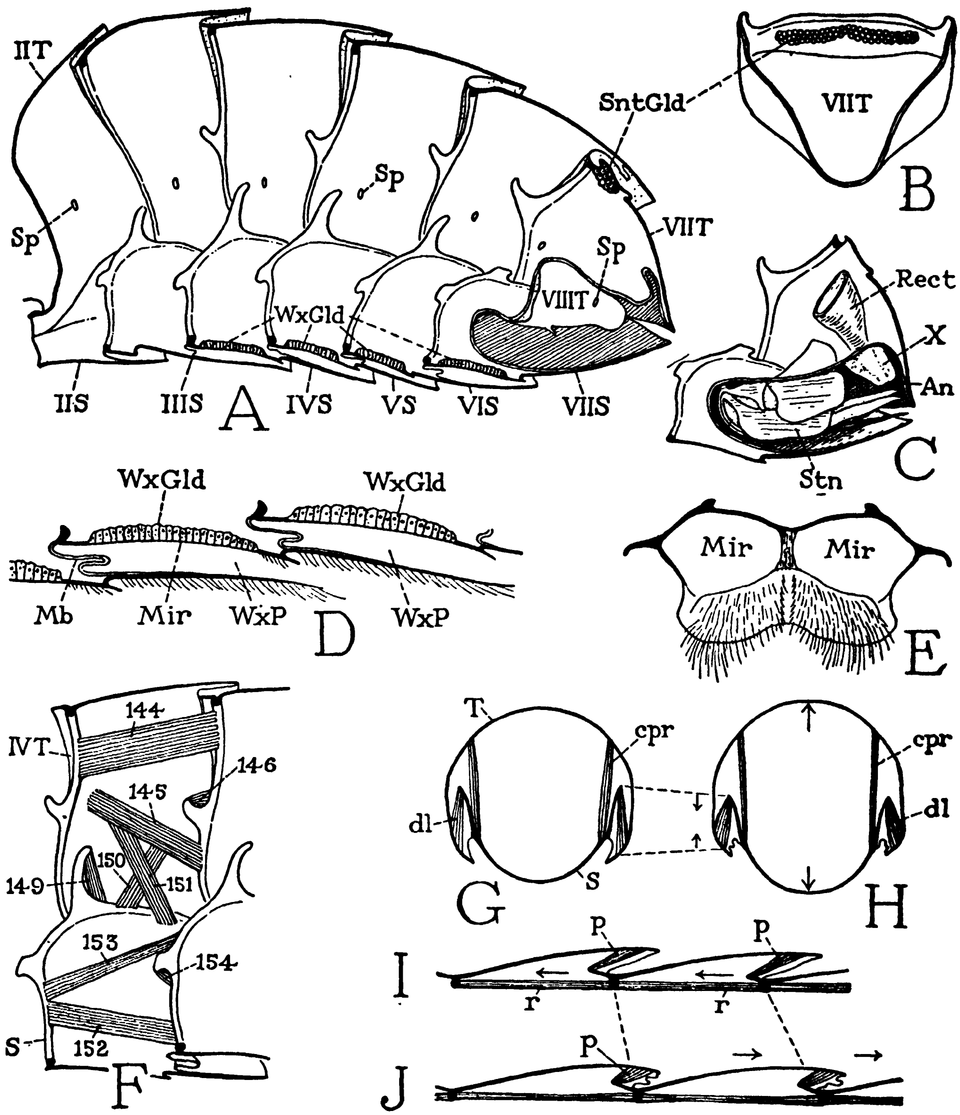



FIGURE 249. The abdomen of the worker bee. A, internal view of right half of abdomen of worker. B, under side of back plate of abdominal segment *VII* showing scent gland. C, end of abdomen opened on left side, showing sting chamber. D, vertical lengthwise section of two consecutive sternal plates, showing wax glands and wax pockets (as seen also at A). E, outer surface of a sternal plate (segment *V*) with smooth "mirrors" (*Mir*) beneath wax glands. F, diagram of muscles in right half of a typical abdominal segment. G, H, diagrams illustrating mechanism of vertical compression and expansion of an abdominal segment. I, J, diagrams of mechanism of lengthwise contraction and protraction of abdominal segments.

*An*, anus; *cpr*, compressor muscle; *dl*, dilator muscle; *Mb*, intersegmental membrane; *Mir*, mirror; *p*, protractor muscle; *r*, retractor muscle; *Rect*, rectum; *S*, sternum; *SntGld*, scent gland; *Sp*, spiracle; *Stn*, sting; *T*, tergum; *WxGld*, wax gland; *WxP*, wax pocket; *X*, ninth abdominal segment, concealed in sting chamber. (*Drawing courtesy Bureau of Entomology and Plant Quarantine*)

plates and push the segments apart. The vertical movements are produced in the same way by lateral muscles between the terga and sterna. The *compressor muscles* are two crossed muscles in each side of each segment (F, 150, 151), which by contracting (G, *cpr*) draw the tergum and sternum together. The *dilator muscles* extend from the upper ends of long lateral sternal arms (F, 149; G, *dl*) to the lower edges of the terga, and hence expand the abdomen vertically by pulling the edges of the overlapping plates toward each other (H).

The abdomen is connected with the propodeum of the thorax by a short but narrow stalk, the *petiole,* and acquires thereby a high degree of mobility on the thorax. The principal muscles that move the abdomen as a whole are those of the transposed propodeum, which are the intersegmental muscles between the primary first and second abdominal segments.

The external features of chief interest in the bee's abdomen are the *wax glands* with their accompanying wax pockets, the *scent gland,* and the *sting.* In the drone there are two pair of small plates associated with the genital aperture, but they will be described in connection with the other parts of the reproductive system.

## The Wax Glands

The abdominal sterna have long posterior extensions that widely underlap in each case the sternum of the segment behind (Fig. 249, A). The anterior underlapped parts of sterna *IV, V, VI,* and *VII* in the worker each present two large, smooth, glistening oval areas separated by a narrow, darker median band (E): the exposed part beyond is densely clothed with hairs. The polished oval spaces are known as the *mirrors* (*Mir*); they are the areas of the sterna covered internally by the wax-secreting glands (A, D, *WxGld*). These glands are merely specialized parts of the body-wall epidermis, which, during the wax-forming period in the life of the worker, become greatly thickened and take on a glandular structure. The wax is discharged as a liquid through the mirrors and hardens to small flakes in the pockets (D, *WxP*) between the mirrors and the long underlapping parts of the preceding sterna. After the wax-forming period the glands degenerate and again become a flat layer of cells.

## The Scent Gland

The scent-producing gland of the worker bee lies internally against the back of abdominal segment *VII* (Fig. 249, A, *SntGld*). Seen from the inner surface (B) the gland appears as a band of large cells extending crosswise near the anterior margin of the tergal plate. Outside the gland (A) is an elevation of the tergum with a smooth and slightly concave surface, suggestive of being an evaporating dish for the gland secretion; but the gland cells discharge their products by minute, individual ducts opening into the pocket at the base of the tergal plate.

## The Sting

The sting of the bee is similar in its structure and mechanism to an egg-laying organ, known as the *ovipositor*, possessed by many other female insects, including most of the Hymenoptera. The ovipositor of some species is also a piercing organ capable of being inserted into the bodies of other insects, or of penetrating plant tissues, even hard wood; but in such cases its function is merely to form a hole in which the eggs may be deposited. The sting of the stinging Hymenoptera, therefore, is very evidently an ovipositor that has been remodeled in a few ways for the injection of poison instead of eggs.

The sting is ordinarily contained within a chamber at the end of the abdomen (Fig. 249, C) from which only its effective part, the familiar, tapering, sharp-pointed *shaft* is protruded. If the sting is removed from the body, or is examined in place within the abdomen, it is seen to include a large basal structure (Fig. 250, A) from which the shaft (*Shf*) is suspended by a pair of curved arms (only one arm visible on each side). The sting base in turn is suspended in the membranous wall of the sting chamber (Fig. 249, C).

Though the shaft of the sting appears to be a solid structure, it is composed of three separable pieces, one above termed the *stylet* (Fig. 250, A, C, *Stl*) and two below known as the *lancets* (*Lct*). The stylet tapers to a point, but swells proximally into a long bulblike enlargement (A, *blb*) containing a deep cavity open below and continued as a shallow groove on the undersurface of the stylet (C). The lancets are long, slender, sharp-pointed rods lying side by side along the lower edges of the bulb and stylet. Grooves on their upper surfaces fit snugly over tracklike ridges of the bulb and stylet (C) so that, while held firmly in place, the lancets can slide freely back and forth. The lower edges of the lancets are in contact with each other; there is thus enclosed between the stylet and the lancets a channel (C, *pc*) leading from the cavity of the bulb to the tip of the shaft.

This channel is the *poison canal* of the sting. The poison liquid is poured into the base of the bulb from a large *poison sack* (A, *PsnSc*), which is the reservoir of a long, slender poison gland (Fig. 256, C, *PsnGld*) that opens into its upper end. A second thick tubular gland associated with the sting (Fig. 250, A, *BGld*) opens externally below the base of the bulb. The terminal part of the stylet is armed with three pair of small lateral teeth; the lancets each have a series of nine or ten recurved barbs along the outer side near the end (Fig. 250, B).

The basal arms of the shaft are each composed of two closely appressed rods, one (Fig. 250, A, *2r*) narrowly attached to the base of the bulb and the other (*1r*) continuous with the lancet of the same side. The lancet arms slide on the bulb arms by ridge-and-groove connections continuous with those by which the lancets slide on the bulb and stylet.

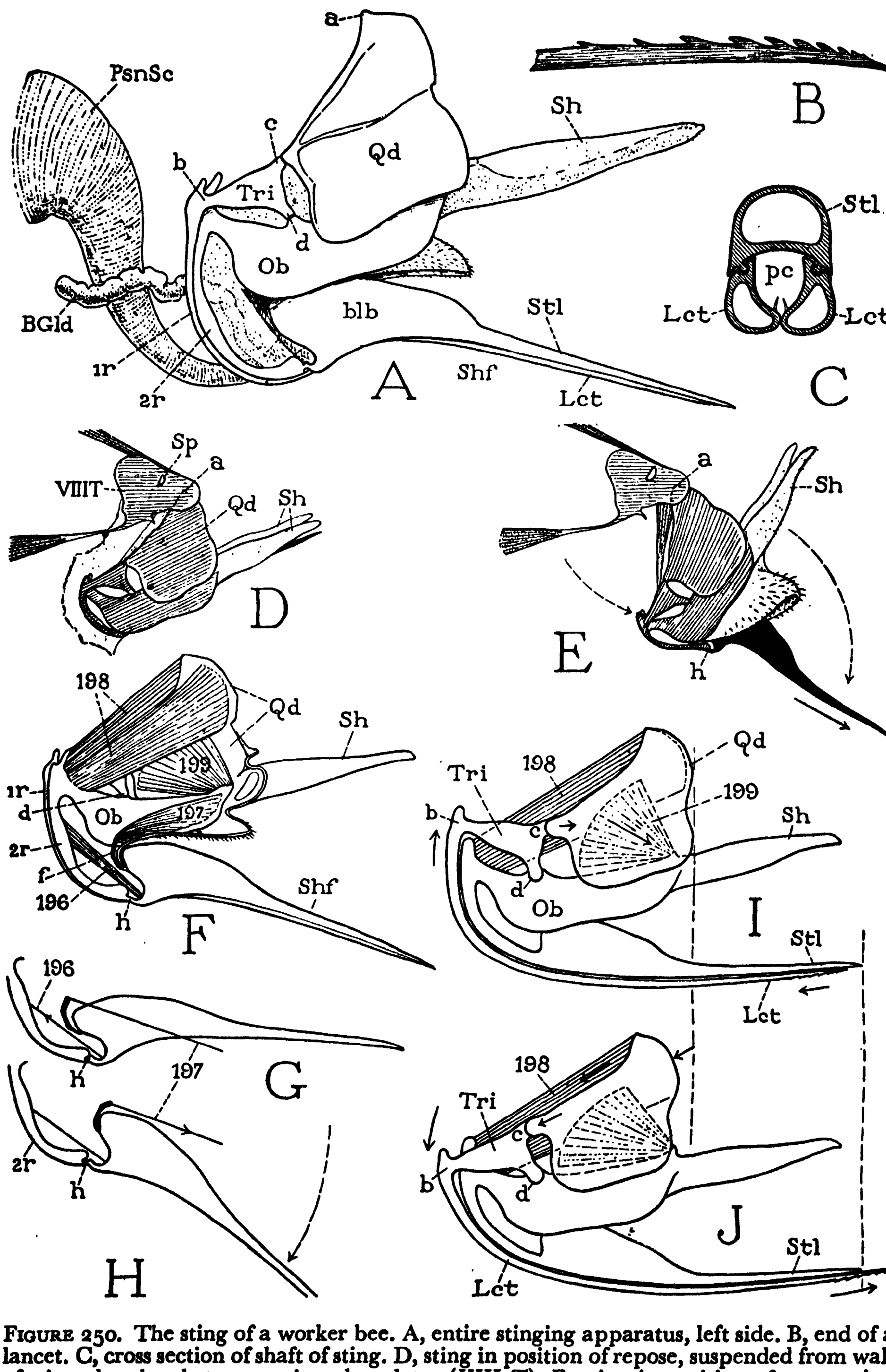



FIGURE 250. The sting of a worker bee. A, entire stinging apparatus, left side. B, end of a lancet. C, cross section of shaft of sting. D, sting in position of repose, suspended from wall of sting chamber between spiracular plates (*VIII T*). E, sting in position of protraction

The supporting basal structure of the sting is the motor apparatus of the stinging mechanism. On each side it presents three plates. The largest and uppermost plate is a four-sided sclerite known as the *quadrate plate* (Fig. 250, A, *Qd*); another is a small *triangular plate* (*Tri*) lying before the quadrate plate and connected anteriorly by its apex with the upper end of the basal arm of the lancet of the same side (*1r*); the third (*Ob*), because of its shape called the *oblong plate,* lies below the other two and is connected anteriorly with the corresponding basal arm of the bulb (*2r*). Posteriorly each oblong plate bears a long, soft, fingerlike lobe (*Sh*). The triangular plate articulates by its upper basal angle (*c*) with the anterior angle of the quadrate plate, and by its lower angle (*d*) with the upper edge of the oblong plate. The two quadrate plates are closely associated with two other plates partly overlapping them (D, *VIIIT*), which contain a pair of spiracles and hence are known as the *spiracular plates.* The spiracular plates belong to abdominal segment *VIII,* the quadrate plates to segment *IX*.

When the sting is not in action it is entirely retracted within the sting chamber of the abdomen (Fig. 249, C). In the retracted position (Fig. 250, D) the shaft is turned up so that its base is concealed between the oblong plates and its distal part ensheathed between the two projecting lobes of the latter (*Sh*). The protraction of the shaft from the abdomen (E) involves two simultaneous acts: first, a backward swing of the entire supporting apparatus; second, a downward swing of the shaft on its basal arms until it stands at right angles to the oblong plates. The backward swing of the whole structure gives the outward thrust to the extended shaft. This movement apparently is produced by a sharp upward tilt of sternum *VII* which lies immediately beneath the sting (Fig. 249, C). The deflection of the shaft is caused by the contraction of a pair of large muscles arising on the inner faces of the oblong plates (Fig. 250, F, 197), and inserted on a Y-shaped rod (*f*) attached by its stalk to the base of the bulb. The backward pull of these muscles on the bulb turns the entire shaft downward (H) on the flexible hinges (*h*) between the bulb and its basal arms (*2r*). The retraction of the sting into the chamber probably results from the restoration of sternum *VII* to its usual position; the shaft is drawn up again between the ensheathing lobes by a pair of slender

---

(arrows indicate the two essential movements). F, diagram of sting and its muscles. G, diagram of shaft of sting held in position of repose by muscle *196*. H, same, shaft turned down (as at E) by contraction of muscle *197*. I, J, mechanism of retraction (I) and protraction (J) of lancet.

*a*, attachment of quadrate plate with spiracular plate; *b*, apex of triangular plate continuous with lancet; *BGld*, "alkaline" gland of sting; *blb*, bulb of stylet; *c*, hinge of triangular plate on quadrate plate; *d*, hinge of triangular plate on oblong plate; *f*, forked rod (furcula) giving attachment to depressor muscles (*197*) of shaft; *h*, hinge of bulb with its basal arm (*2r*); *Lct*, lancet; *Ob*, oblong plate; *pc*, poison canal; *PsnSc*, poison sack (see Fig. 256 C); *Qd*, quadrate plate; *1r*, basal arm (ramus) of lancet; *2r*, basal arm of bulb and stylet; *Sh*, sheath lobes; *Shf*, shaft of sting; *Sp*, spiracle; *Stl*, stylet; *Tri*, triangular plate; *VIII T*, spiracular plate associated with sting base. (*Drawing courtesy Bureau of Entomology and Plant Quarantine*)

muscles stretched between the base of the bulb and its supporting arms (Fig. 250, F, G, 196).

When the worker bee stings, the end of the abdomen is abruptly bent downward and with a sudden jab the tip of the out-thrust shaft is inserted into the flesh of the victim. Now another part of the sting mechanism comes into play by which the lancets are alternately forced deeper and deeper into the wound, holding each gain by the recurved points along their sides. The movements of the lancets depend on an interaction between the quadrate plates and the triangular plates of the motor apparatus. Two muscles arising on each quadrate plate (Fig. 250, F, 198, 199) are attached, one (198) on the anterior end of the oblong plate (*Ob*), the other (199) on the posterior end. The alternating pull of these two muscles vibrates the quadrate plate forward and backward (as shown at I and J). The forward movement of the quadrate plate (J) pushes on the upper basal angle (*c*) of the triangular plate (*Tri*); the latter revolves on its fulcral support (*d*) on the oblong plate, and the depression of its apical angle (*b*) pushes down on the basal arm of the lancet (*Lct*); and the lancet thus slides backward on the stylet and its tip protrudes from the end of the shaft. Conversely, as long as the lancet is free to move, the contraction of muscle *199* (I) pulls the quadrate plate backward, lifts the apical angle (*b*) of the triangular plate, and retracts the lancet.

If, however, the stinging bee has succeeded in inserting the point of the sting in an intended victim and the lancet first thrust out holds in the skin by means of its barbs, the force of the retractor muscle (I, *199*) is now expended on the oblong plate which revolves downward anteriorly on its articulation (*d*) with the triangular plate and drives the attached stylet into the wound made by the lancet. The lancet of the opposite side is then thrust out in the same way as the first and takes a still deeper hold in the flesh. Thus by repeated alternating thrusts of the lancets the point of the shaft sinks deeper and deeper, and the action of the sting apparatus continues even when the sting is separated from the body of the bee. Valves on the basal parts of the lancets drive the poison through the poison canal of the shaft and the liquid is expelled, not at the penetrating tip of the sting, but from a ventral cleft near the ends of the lancets.

The sting of the queen is longer than that of the worker and is more solidly attached within the sting chamber. Its shaft is strongly decurved beyond the bulb. The lancets have fewer and smaller barbs than those of the worker, but the poison glands are well developed and the poison sack is very large.

## The Alimentary Canal

The food tract begins at the *mouth* in the lower wall of the head (Fig. 251, A, *Mth*). The mouth opens into the cavity of the *sucking pump (Pmp)* which stands vertically in the head. At its upper end the pump

narrows to the slender, tubular *oesophagus* (*Oe*), which turns posteriorly through the neck and thorax, and in the anterior end of the abdomen enlarges into a thin-walled sack (*HS*). This sack corresponds with the *crop* of other insects, but it is commonly known to students of the bee as the *honey stomach* because it is used by the bee for carrying nectar or honey. Following the honey stomach is a short narrow part of the food canal called the *proventriculus* (*Pvent*). Next comes a long, thick, cylindrical sack (*Vent*) looped crosswise in the abdomen, usually in an S-shaped curve, which is the true stomach of the insect, or *ventriculus*. Following the

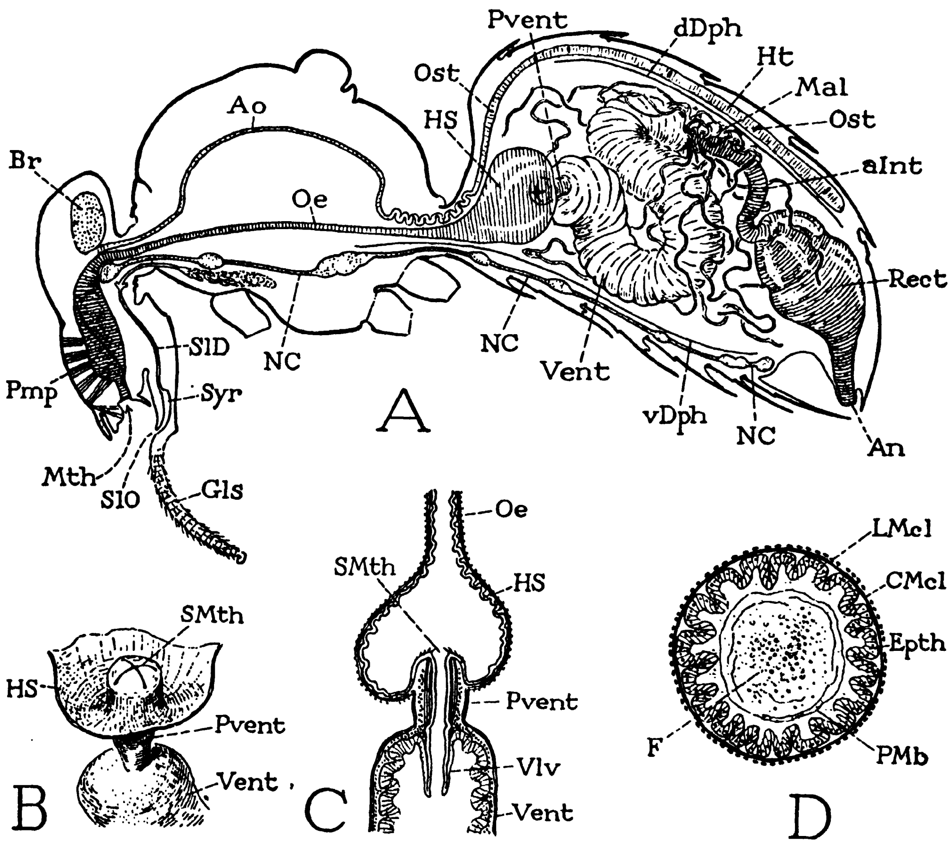



FIGURE 251. The alimentary canal and other internal organs of a worker bee. A, lengthwise section of a worker bee, showing alimentary canal, dorsal blood vessel, diaphragms, brain, and ventral nerve cord. B, inner end of honey stomach cut open to show stomach mouth (*SMth*) at summit of proventriculus (*Pvent*). C, lengthwise section of honey stomach, proventriculus and anterior end of ventriculus. D, cross section of stomach (ventriculus). *An*, anus; *aInt*, anterior intestine; *Br*, brain; *CMcl*, circular muscles; *dDph*, dorsal diaphragm; *Epth*, epithelium (cellular layer of stomach); *F*, food material; *Gls*, tongue; *HS*, honey stomach; *Ht*, heart; *LMcl*, longitudinal muscles; *Md*, mandible; *Mth*, mouth; *NC*, nerve cord; *Oe*, oesophagus; *Ost*, ostium; *Pmp*, sucking pump; *PMb*, peritrophic membrane; *Pvent*, proventriculus; *Rect*, rectum; *SlD*, salivary duct; *SlO*, salivary orifice; *SMth*, stomach mouth; *Syr*, salivary syringe; *vDph*, ventral diaphragm; *Vent*, ventriculus; *Vlv*, proventricular valve. (*Drawing courtesy Bureau of Entomology and Plant Quarantine*)

stomach is the intestine, but the latter is distinctly divided into two parts: first, a narrow *anterior intestine* (*aInt*), which is looped or coiled in various ways according to the position of the stomach; and second, a large, pear-shaped *posterior intestine,* or *rectum* (*Rect*), opening by its tapering extremity through the *anus* (*An*) into the cavity that contains the sting (Fig. 249, C).

The structure of the sucking pump has already been described in connection with the feeding mechanism. The oesophagus is a tube with muscular walls, which passes the food along its length by successive waves of constrictions in the manner by which most animals swallow their food. The honey stomach, being the crop of the insect, serves the bee not only as a nectar-carrier but also as a storage place for food material. It is greatly distensible because its inner wall is thrown into numerous folds (Fig. 251, C, *HS*). The proventriculus is a regulatory apparatus that controls the entrance of food into the stomach. Its anterior end projects like a thick plug into the honey stomach (B, C) and contains an X-shaped opening between four thick, bristly, triangular, muscle-controlled lips (*B, SMth*). This structure constitutes a *stomach mouth;* by its action nectar or honey can be retained in the honey stomach while pollen is taken out and delivered to the ventriculus. The posterior end of the proventriculus extends in a long funnellike fold (C, *Vlv*) into the anterior end of the ventriculus (*Vent*), and probably acts as a valve to prevent regurgitation from the stomach.

The ventriculus is the part of the insect alimentary canal in which digestion and absorption of food material take place. Its inner wall (Fig. 251, D, *Epth*) is a thick cellular layer (epithelium) thrown into numerous crosswise folds that not only greatly increase the extent of the digestive surface but also allow for expansion. Outside the cellular wall is first a layer of circular muscle fibers (*CMcl*), and surrounding the latter a sheath of lengthwise fibers (*LMcl*). Inside the stomach is a very thin, irregular *peritrophic membrane,* or several such membranes (*PMb*), forming a delicate cylindrical covering around the food mass (*F*). The cellular layer of the ventricular wall secretes the digestive juices and enzymes; the products of digestion go through the thin peritrophic membrane and are discharged through the stomach wall directly into the surrounding blood.

The intestinal tract usually is a relatively small part of the food canal. The narrow anterior intestine and the sacklike rectum (Fig. 251, A, *aInt, Rect*) serve principally for the discharge of waste matter and for the absorption of water, but the rectum is also a storage chamber for the retention of feces until the latter can be evacuated outside the hive. In overwintering bees the rectum may become so greatly distended as to occupy a large part of the abdominal cavity before defecation occurs.

At the junction of the intestine with the ventriculus there open into the intestine a great number of long, threadlike tubes, probably a hundred or more of them. These tubes are known as the *Malpighian tubules*

(Fig. 251, A, *Mal*); they are not digestive glands but excretory organs that remove waste products of metabolism from the blood, including both nitrogenous substances and salts. The tubules extend long distances in the body cavity, winding and twisting in numerous convolutions through the spaces about the other organs, where they are directly bathed by the blood. Their products discharged into the intestine are eliminated along with the waste food matter.

## The Blood, the Organs of Circulation, and Associated Tissues

The spaces in the body of an insect not occupied by the organs or other tissues are filled with a liquid which is the *blood,* or *haemolymph.* Floating in the blood are numerous blood cells, or *haemocytes,* of several kinds, but the blood cells do not serve for the transport of oxygen; they resemble the white blood cells of vertebrate animals. The blood liquid also carries but little oxygen; its principal known functions are the distribution of digested food material absorbed from the alimentary canal, the reception of waste products of metabolism which are removed by the excretory organs, and the transport of carbon dioxide to be eliminated through the respiratory organs and the skin. The blood is kept in circulation through the body by a pulsating tubular blood vessel and by vibratory membranes. The blood of the honey bee is of a pale amber color.

The single blood vessel is a long slender tube (Fig. 251, A, *Ao, Ht*) extending forward along the midline of the back in the abdomen from abdominal segment *VI* through the thorax and into the head, where it opens beneath the brain (*Br*). The abdominal part of the vessel is called the

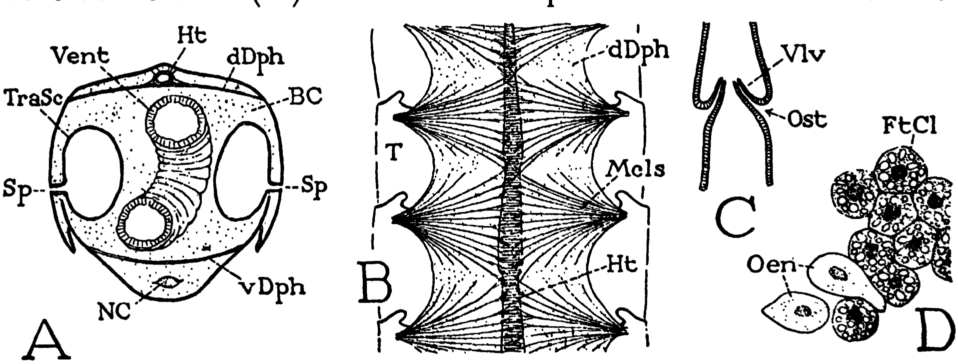



FIGURE 252. The body cavity, diaphragms, heart, fat cells, and oenocytes. A, diagrammatic cross section of an abdominal segment. B, part of heart and dorsal diaphragm seen from below against the abdominal terga. C, lengthwise section of heart through a pair of ostia. D, group of fat cells and oenocytes.
*BC*, body cavity (filled with blood); *dDph*, dorsal diaphragm; *FtCl*, fat cells; *Ht*, heart; *Mcls*, muscles; *NC*, nerve cord; *Oen*, oenocytes; *Ost*, ostium; *Sp*, spiracle; *T*, tergum; *TraSc*, tracheal air sack; *vDph*, ventral diaphragm; *Vent*, ventriculus; *Vlv*, valvelike inner end of funnel-shaped ostial opening. (*Drawing courtesy Bureau of Entomology and Plant Quarantine*)

*heart* (*Ht*) and the thoracic part, the *aorta* (*Ao*). The sides of the heart are perforated by five pair of slits, the *ostia* (*Ost*), in abdominal segments *II* to *VI*, inclusive, through which the blood enters the heart. The heart drives the blood forward by rhythmic pulsations of its muscular walls. The lips of the ostia project forward into the heart cavity (Fig. 252, C) and act as valves (*Vlv*) to prevent the escape or backward flow of the blood. The aorta has no ostia, is thrown into numerous small loops where it enters the thorax, and ends openly beneath the brain.

The heart is supported on a thin membrane, called the *dorsal diaphragm* (Fig. 252, A, *dDph*), stretched across the upper part of the abdominal cavity in segments *III* to *VII* (Fig. 251, A). The membrane contains five pair of fan-shaped bundles of fine muscle fibers attached laterally on the anterior margins of the tergal plates and spreading toward the heart where the fibers break up into numerous branching fibrils (Fig. 252, B, *Mcls*). The diaphragm shuts off above it a *pericardial cavity* containing the heart, but its lateral margins are free between the muscle attachments, thus leaving openings by which the blood can enter the pericardial cavity from the general body cavity. A rhythmic contraction of the diaphragm muscles causes the dorsal diaphragm to pulsate in a forward direction.

In the ventral part of the body above the nerve cord is a similar *ventral diaphragm* (Fig. 252, A, *vDph*), but this diaphragm extends from the metathorax into segment *VII* of the abdomen. It is more strongly muscular than the dorsal diaphragm and beats in a backward direction.

The blood discharged into the head from the aorta bathes the organs in the head and flows backward through the thorax and the abdomen by fairly well-defined channels, circulating also through the antennae, the wings, and the legs. The backward flow of the blood in the abdomen is assisted by the pulsations of the ventral diaphragm; from the lower part of the abdomen it goes upward into the pericardial cavity where it is driven forward along the sides of the heart probably by the vibrations of the dorsal diaphragm, and finally again enters the heart through the ostia. Small pulsating membranes occur in the head between the antennal bases and in the upper part of the thorax, but the movements of these membranes appear to be produced by neighboring muscles.

Scattered all through the body cavity of the insect but especially in the abdomen are irregular masses of a soft, usually white tissue composed of large, loosely united cells (Fig. 252, D, *FtCl*). These cell masses are known collectively as the *fat body* because the cells contain enmeshed in their cytoplasm small droplets of oily fat. The fat tissue is particularly abundant in the larva; but the larval cells contain, besides large amounts of fat, also glycogen and, toward the end of the larval life, numerous minute protein granules. The fat body, in short, is a storage tissue for the conservation of elaborated food products not immediately needed by the individual. The larval fat cells thus carry over a large supply of food material into the pupal stage where it is thrown out into the blood by dissolu-

tion of the cells, and consumed by the pupal tissues developing into the adult organs. An underfed larva cannot properly transform into a mature bee.

Intermingled with the fat cells are other cells of larger size having a pale yellowish color, known as *oenocytes* (Fig. 252, D, *Oen*), and strands of special cells, called *nephrocytes,* lie along the sides of the heart, but nothing definite is known concerning the functions of these cells.

## The Respiratory System

The chemical changes that go on constantly inside the body cells of living things require oxygen for consumption, and produce carbon dioxide which must be eliminated. All multicellular animals, therefore,

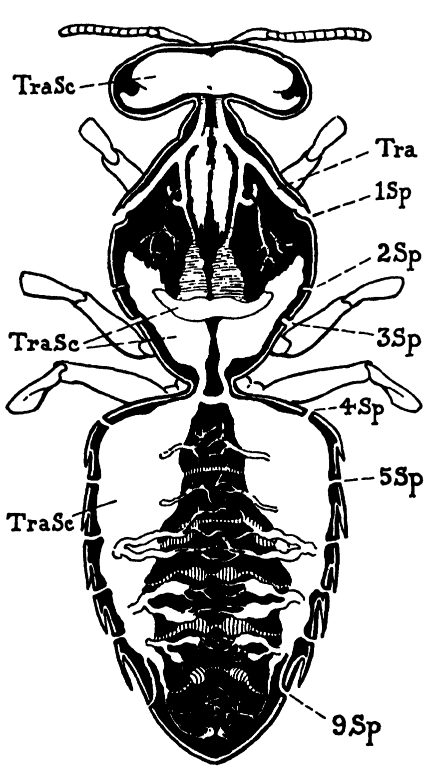



FIGURE 253. General view of the tracheal respiratory system of a worker bee, seen from above. *1Sp-9Sp*, spiracles; *Tra*, tracheal trunk from first spiracle; *TraSc*, tracheal sacks. Though not designated, the sixth, seventh, and eighth spiracles are the openings shown between the fifth and ninth spiracles. (*Drawing courtesy Bureau of Entomology and Plant Quarantine*)

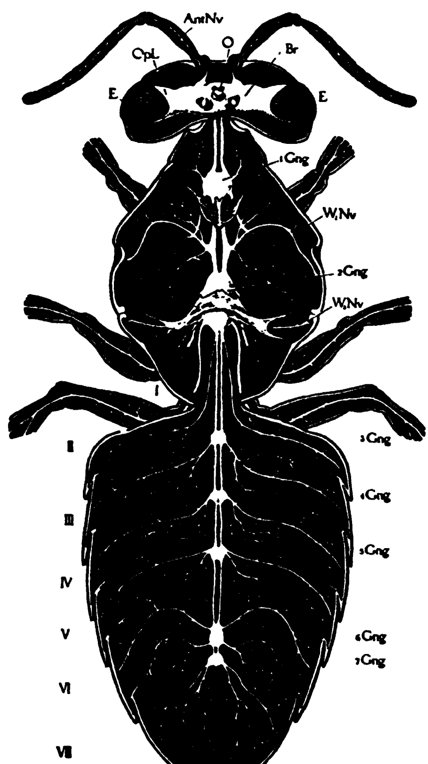



FIGURE 254. The nervous system of a worker bee seen from above. *AntNv*, antennal nerve; *Br*, brain; *E*, compound eye; *1Gng-7Gng*, ganglia of ventral nerve cord; *I*, propodeum; *II-VII*, abdominal segments; *O*, ocellus; *Opl*, optic lobe of brain; *W1Nv*, nerve to first wing; *W2Nv*, nerve to second wing. (*Drawing courtesy Bureau of Entomology and Plant Quarantine*)

are confronted with the problem of how to supply their tissues with oxygen and how to remove the carbon dioxide. Some have solved the problem in one way, others in other ways, but the anatomical means adopted, whatever its nature, constitutes a *respiratory system.*

Certain small, soft-bodied insects and some insect larvae have the very simple system of exchanging respiratory gases by diffusion directly through the skin. With most insects, however, the integument is too hard and dense for skin breathing and the majority of species, even very minute insects, have long, tubular, many-branched, thin-walled ingrowths of the integument that conduct air from outside the body to all the living tissues inside the body. These air tubes are called *tracheae;* collectively the tracheae constitute a *tracheal respiratory system.* The fine terminal branches of the tracheae go to practically all the cells of the body, the tissues thus receiving their oxygen direct without transport by the blood. The blood absorbs only what oxygen it needs for its own use.

The tracheal system of the bee is highly elaborate (Fig. 253), but a large part of it consists of air sacks (*TraSc*) which are thin-walled expansions of tracheae. The tracheal tubes open from the exterior by small breathing pores, the *spiracles* (*Sp*), situated along the sides of the body. Most insects have ten spiracles on each side, two on the thorax and eight on the abdomen. The adult honey bee, however, has three thoracic and seven abdominal spiracles because of the transfer of the first abdominal segment to the thorax. The first and largest spiracles of the bee (*1Sp*) lie between the prothorax and the mesothorax, but each is concealed beneath the lateral lobe of the pronotum (Fig. 243, *spl*), and is further protected by a dense fringe of long hairs on the covering lobe. Nevertheless, the first spiracle is entered by the parasitic mites, *Acarapis woodi,* that accumulate in the large tracheal trunk (Fig. 253, *Tra*) proceeding from this spiracle and cause a form of paralysis called acarine disease. The second spiracle (2Sp) is very small and lies between the upper angles of the pleural plates of the mesothorax and metathorax, but is normally concealed between these plates, and therefore is not seen in Figure 243 of the thorax. The third spiracle (*3Sp*) is fully exposed on the side of the propodeum (Fig. 243). The next six (*4Sp-9Sp*) are in the lower parts of the first six tergal plates of the abdomen (Fig. 249, A), but the tenth is not visible externally since it is in the so-called spiracular plate associated with the base of the sting (Figs. 249, A, 250, D, *VIII T*). All the spiracles, except the minute second spiracle, have an apparatus for closing the spiracular orifice to prevent the escape of inhaled air or to control air movement through the tracheae.

Respiration in the bee is effected partly by dorsoventral and lengthwise contractions and expansions of the abdomen, produced as already explained by opposing sets of abdominal muscles (Fig. 249, G-J). For the inhalation of air by respiratory movements, however, it is necessary that some part of the air passages inside the body should be able to expand.

The tracheal tubes are more or less rigid by reason of spiral thickening in their walls that serve to keep them open, and hence do not respond much to increase and decrease of pressure around them. In the bee, therefore, as in most insects that breathe actively, parts of the tracheae are dilated into thin-walled *air sacks* that expand and collapse in the manner of lungs in response to the expansion and contraction of the rigid parts of the body wall. The honey bee is particularly well supplied with tracheal air sacks (Fig. 253, *TraSc*), two large sacks occupying much of the space in the sides of the abdomen while smaller ones are distributed all through the thorax, in the head, and even in the legs.

From the air sacks the tracheae continue as branching tubes that ramify to all the parts of the body, the appendages, and the internal organs. Finally the tracheae end in groups of minute tubes, called *tracheoles*, which terminate blindly against or within the tissue cells. The distal parts of the tracheoles are filled with a liquid that absorbs oxygen from the air delivered through the tracheae. The physiological activity of the cells causes the oxygen-saturated liquid in the tracheoles to be drawn through the tracheole walls and the cell walls into the protoplasm of the cells; when the cell activity (metabolism) decreases or returns to a minimum, the liquid again accumulates in the tracheoles and absorbs a fresh supply of oxygen. The carbon dioxide produced in the cells cannot be directed into the tracheoles; it is mostly discharged directly into the surrounding blood, from which it is carried off by diffusion through the tracheae or through the softer parts of the integument.

The metabolism of insects produces heat as in other animals, and the body temperature increases considerably during muscular activity, but the insect has no means of retaining the heat within its body; consequently it is given off almost immediately by radiation. Beekeepers well know that bees raise the temperature of the hive in winter by rapid vibration of the wings, which involves sustained action of the huge masses of muscle fibers in the thorax.

## The Sensory and Nervous System

A distinctive feature of animals is their ability to adjust their actions to conditions of the environment, particularly changing conditions. Animals are able to do this because they have cells or groups of cells close to the exterior of the body that are specifically sensitive to the common forms of energy in nature that are not destructive to them. These specialized cells and associated structures are known as *sense organs*, but the term does not necessarily imply conscious perception on the part of the animal.

From the receptive cells of the sense organs, *sensory nerves* extend inward to the central nervous system. Another set of fibers, called *motor nerves*, goes outward from cells in the central system to the body muscles and glands. A third set of intermediary *association fibers* connects the

ends of the incoming sensory nerves with the roots of the outgoing motor nerves. In this way there is established a nerve circuit from the outlying sense organs through the central system to the muscles or glands, and the stimuli received from outside the body thus set up a nerve impulse that finally activates the motor system, or causes certain glands to produce a secretion. What the animal does in response to an external stimulus is called its *reaction.*

The nature of the reaction depends on the external stimulus and on the internal nerve pathways that are affected. If the animal has conscious control of its actions, volition may determine the path of the outgoing nerve impulse, otherwise the action is a *reflex;* co-ordinated reflexes are *instincts.* The sensory and nervous systems of insects are well developed and organized, and the honey bee is in many respects one of the most highly endowed in its powers of sensory reception and motor reaction.

Reaction to touch, or external pressure, is probably the most primitive of all the senses. In adult insects, as compared with soft-skinned larvae, the general body surface has relatively little sensitiveness to pressure because of the hardness of its outer covering. Hence, most of the sensory nerves of the skin end in cells at the bases of hairs. The hairs being delicately poised are easily moved by contact with objects or currents of air. Therefore, an innervated hair and its associated sense cell constitute an *organ of touch.* It is not known how many of the hairs of the bee are sensory organs, but innervated hairs occur on various parts of the body and appendages, and are particularly numerous on the antennae. Some insects respond to sound by the vibration of sensory hairs. We have no definite information on the hearing powers of bees, and the bee has no known auditory organs.

Some very small, thin-walled hairs of the bee, or hairlike structures reduced to small pegs, are supposed to be capable of being stimulated by minute particles of matter in air or liquids, and hence are regarded as *organs of smell or taste.* These organs are innervated each from a group of sense cells which sends a nerve strand into the hair or peg. Organs of this kind occur on the antennae and on parts near the mouth; some on the antennae are sunken into deep flask-shaped cavities. The most numerous organs on the antennae, however, appear on the surface as minute oval disks or plates. Each plate has a groove around the margin and covers a large group of sense cells. These structures are known as *plate organs;* they are supposed to be the principal organs of smell in the bee, though it is difficult to understand from their structure how they can be receptive to odor particles. Definite proof of their olfactory function has not been produced. Yet there is little doubt that the antennae are the principal seat of the olfactory sense of the bee. It has been estimated that there are 5 or 6 thousand plate organs on the antennal flagella in the worker, 2 or 3 thousand in the queen, and perhaps 30 thousand in the drone.

Still other organs, having the form of minute bells or inverted cups sunken into the body wall with a nerve ending inside, are distributed in groups on various parts of the body and appendages. These organs have been described as "olfactory pores," but recent experiments appear to show that they respond to strains, stresses, or bending of the integument, and thus give the insect "information" concerning its own actions.

Imaginative people like to speculate on the possibility of insects having some sense "totally unknown to us," but, considering that the senses are internal reactions on the part of the animal to external conditions of the environment, a supposed "unknown sense" must be based on something real in nature. An insect's reactions to sensory stimuli can be determined experimentally and its sense organs can be studied under the microscope, but inasmuch as its sense organs are so different from ours, and because various kinds of them occur on the same parts of the body or appendages, it is a difficult matter in the case of most of them to determine specifically what stimulus is effective on each kind of organ.

The best known of the insect sense organs are the eyes, because an insect eye is like any other eye in that its essential parts are an external *lens* for focusing light, and a sub-lying, light-sensitive *retina* connected by nerves with the brain. The bee, as we have observed, has three small simple eyes, or *ocelli,* on the top of the head (Fig. 239, A, *O*), and a pair of large *compound eyes* (*E*) on the sides of the head. A simple eye has one lens for the entire retina; a compound eye has many small lenses, and the retina is divided into parts corresponding with the lenses. It is supposed that the insect "sees" with a compound eye as many points of light as there are divisions of the eye, and thus gets a mosaic picture of the object or scene before it—and there may be several thousand separate light-receptive parts of the eye. However, it is impossible for us to know what the final effect on the insect's brain may be. It is certain that insects respond most quickly to movements of objects, but many insects, including the honey bees, perceive differences of color, shape, and position. Most insects "see" the higher colors of the spectrum visible to us (green, blue, violet), and even the ultraviolet which we do not see, but they are more or less insensitive to the lower red rays.

The ocelli have been supposed to be organs for close vision, but a current idea of their function is that they keep the insect continually in a state of stimulation to light, and thus make the compound eyes more quickly responsive. Many larval insects and other arthropods such as spiders have ocelli but no compound eyes.

The central nervous system of the bee (Fig. 254), as in insects generally, is fairly simple in its general structure. It consists of a *brain* (*Br*) in the head above the pharynx, and of a *ventral nerve cord* in the lower part of the body extending from the head to the posterior part of the abdomen. The brain is principally a sensory center, as it receives the nerves from the eyes and the antennae. The ventral nerve cord consists of a series of

small, segmental nerve masses, or *ganglia,* united by paired intervening *connectives.* The first three ganglia of the ventral system are always condensed into a large composite ganglion, termed the *suboesophageal ganglion,* lying in the lower part of the head and supplying nerves to the feeding organs. The first body ganglion (*1Gng*) pertains to the prothorax. The second in the honey bee (2*Gng*) lies in the posterior part of the thorax, but it is composed of four primary ganglia belonging to the mesothorax, the metathorax, the propodeum, and the first abdominal segment, and supplies nerves to all these segments. In the abdomen are five ganglia. The first two (*3Gng, 4Gng*) are displaced forward so that each innervates the segment behind it; the third (*5Gng*) lies in its own segment (*V*) and gives its nerves to this segment; the fourth (*6Gng*) is in segment *VI* but innervates segments *VI* and *VII;* the fifth (*7Gng*), in segment *VII,* supplies nerves to segments *VIII, IX,* and *X.*

The brain and the ventral ganglia are masses of nerve cells and nerve fibers. The cells of the central system give rise to the fibers of the motor and the association nerves, but the fibrous parts of the ganglia include also the branching ends of the incoming sensory nerves from the peripheral sensory nerve cells. The organization of the brain or of a ventral

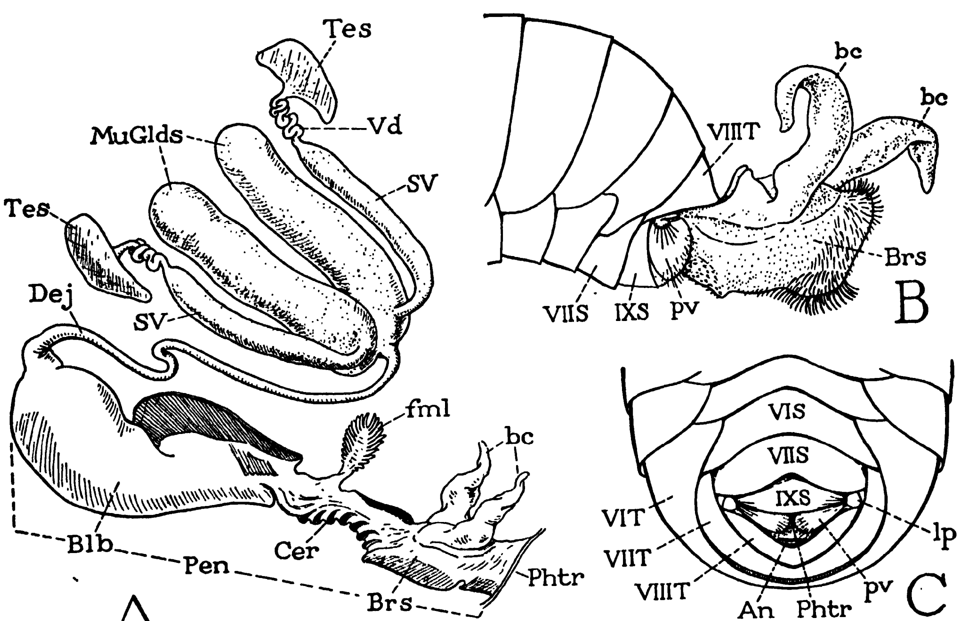



FIGURE 255. The reproductive organs of the drone. A, general view of internal organs of reproduction as seen from left side. B, end of the abdomen of a drone with penis partly everted. *C*, end of drone abdomen, under surface, (penis not everted).
*An,* anus; *bc,* bursal cornua; *Blb,* bulb of penis; *Brs,* bursa of penis; *Cer,* neck (cervix) of penis; *Dej,* ejaculatory duct; *fml,* fimbriate lobe; *lp,* parameral plate; *MuGlds,* mucous glands; *Pen,* penis; *Phtr,* external opening of inverted penis; *pv,* penis valve; *SV,* seminal vesicle; *Tes,* testis; *Vd,* vas deferens; *VI S-IX S,* sternal plates of abdomen; *VI T-VIII T,* tergal plates of abdomen. (*Drawing courtesy Bureau of Entomology and Plant Quarantine*)

ganglion depends mostly on the intricate tracts of intercommunication formed by the association fibers, which connect all parts of the central system. The brain of an insect owes its importance to the fact that it receives the sensory nerves from the eyes and the antennae, and transmits the nervous impulses from these sensory organs to the motor centers of the ventral nerve cord. The environmental stimuli received through the eyes and the antennal sense organs thus direct many of the insect's natural activities. If the head is removed from the insect it is deprived of these stimuli, as well as the ability to eat, but still retains the power of acting through its body motor centers. A decapitated insect is therefore able to walk or even to fly, and a bee without a head is even able to sting.

## The Reproductive System

The reproductive organs of insects usually include external and internal structures, but in the honey bee the organs that subserve the reproductive function are almost entirely internal, the intromittent organ of the drone being a large sack within the abdomen that is everted only at the time of mating, and the instrument of the female used for egg laying by other insects being converted into a sting. Furthermore, the organs are fully developed only in the drone (Fig. 255, A) and the queen (Fig. 256, A). Female organs are present in the worker, but they are greatly reduced in size (Fig. 256, C), and only under certain conditions do they produce eggs. The mature reproductive cells of the male and the female, respectively, are the *spermatozoa* and the *eggs,* or *ova,* but they are developed from primary germ cells, set apart as such in the young embryo, that have little to distinguish them visibly from other cells of the body.

### The Male Reproductive Organs

The organs of the male that contain the primary reproductive cells, and in which the latter develop into spermatozoa are the *testes.* In the drone bee the testes are a pair of small flattened bodies (Fig. 255, A, *Tes*) lying in the sides of the abdomen. From each testis there proceeds posteriorly a duct, the *vas deferens* (plural *vasa deferentia*), at first coiled (*Vd*), but soon enlarging into a long slender sack, the *seminal vesicle* (*SV*). The narrowed posterior ends of the two vesicles enter the lower ends of a pair of huge *mucous glands* (*MuGlds*), lying side by side, and the two glands open together into a single long outlet tube, which is the *ejaculatory duct* (*Dej*). Finally, the ejaculatory duct opens into the anterior end of a large complex structure (*Pen*), termed the *penis* because by inversion at the time of mating it serves to discharge the spermatozoa.

Three consecutive parts may be noted in the structure of the inverted penis. The inner half is a large pear-shaped swelling, or *bulb* (*Blb*), which receives the ejaculatory duct at its anterior end, and has a pair of dark plates in its thick dorsal wall. The bulb passes into a narrowed, usually

twisted neck, or *cervix* (*Cer*), having a series of dark crescent-shaped thickenings along its lower side, and a fringed lobe (*fml*) projecting from its dorsal wall. The neck ends in a large thin-walled sack, or *bursa* (*Brs*), from which project a pair of crumpled hornlike pouches, the *bursal cornua* (*bc*). The bursa opens to the exterior by a wide orifice (*C, Phtr*) beneath the anus (*An*) and between a pair of small valvelike plates (*pv*). These plates and a still smaller pair (*lp*) at their outer angles are the only representatives in the honey bee of a large, often complex, external copulatory organ present in most other male Hymenoptera.

The mature spermatozoa are minute bodies with long vibratile tails. From the testes they pass down the vasa deferentia into the sperm vesicles, where they are temporarily stored with their heads buried in the soft cellular walls of the vesicles. In the mating season, spermatozoa are sent on down through the ejaculatory duct in a secretion from the mucous glands, and a mass of sperm and mucus now fills the bulb of the penis.

## The Female Reproductive Organs

In the female the primary germ cells are housed in the *ovaries*, and in these organs they undergo all but the last stage of development into eggs ready for fertilization. The ovaries of the queen bee (Fig. 256, A, *Ov*) are two huge, pear-shaped masses of slender, closely packed tubules, termed *ovarioles* (*B*). At the posterior end of each ovary the ovarioles come together in a *lateral oviduct* (A, *Odl*) and these two ducts unite in a short *common oviduct* (*Odc*). The last is continuous with a wide terminal sack, the *vagina* (*Vag*), which opens to the exterior by a median orifice (*VO*) in a depression of the body wall at the base of the sting. At the sides of the genital orifice are two other openings (*PO*) which are the mouths of two large pouches (*P*) embracing the sides of the vagina. Lying on the dorsal wall of the vagina is a spherical body (*Spt,* shown turned to one side in the figure), which is the female receptacle for the spermatozoa and is hence termed the *spermatheca.* The spermatheca is connected with the vagina by a short duct (*SptDct*). A pair of tubular *spermathecal glands* (*SptGld*) open into the distal part of the duct.

The eggs are developed within the ovarioles of the ovaries from the primary female reproductive cells, which are lodged in the upper ends of the tubules (Fig. 256, B, *GCls*). As the eggs mature the young ovarioles lengthen and carry the eggs with them in swellings of their walls, called *egg chambers* or *follicles;* but between successive egg chambers are masses of nutritive cells that will be absorbed as food (yolk) by the growing eggs. These food cells are known as *nurse cells.* Each mature ovariole, therefore, presents a succession of alternating egg chambers (*B, EC*) and nurse-cell chambers (*NC*). In the upper parts of the tubes the nurse-cell chambers are larger than the egg chambers, but in the lower parts the size relation becomes reversed because of the progressive absorption of the nurse-cells by the egg cells (*E*). The full-grown eggs in the lower ends of the

ovarioles have absorbed practically all of their accompanying nurse-cells, and the cellular walls of the enclosing follicle now secrete over each egg a thin shell, known as the *chorion*. The chorion is complete except at one point on the anterior pole of the egg, where a minute opening, the *micropyle*, is left to give entrance to the spermatozoa.

### Insemination of the Queen and Fertilization of the Eggs

At the time of mating, the sperm mass in the penis bulb of the drone is discharged by eversion of the penis into the vaginal pouch of the female. It has been supposed that the male organ is first anchored in the female by the eversion of its lateral cornua (Fig. 255, A, *bc*) into the lateral genital pouches of the queen (Fig. 256, A, *P*), but apparently this plausible

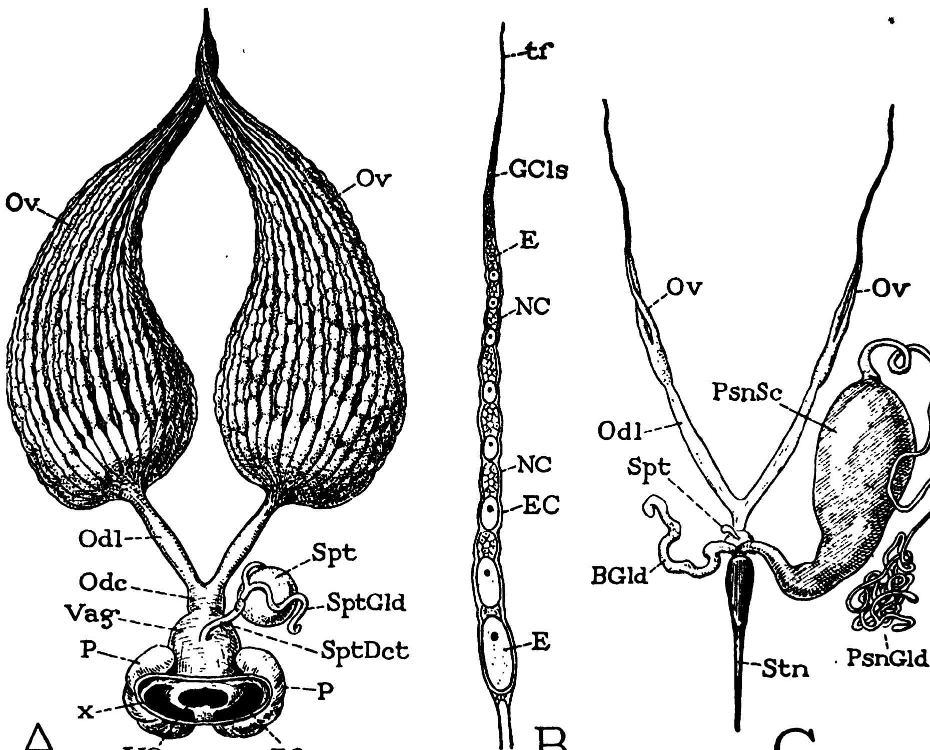



FIGURE 256. The female reproductive organs. A, ovaries, genital ducts, and genital pouches of the queen. B, single ovariole, diagrammatic, showing succession of egg cells and nurse cells. C, reproductive organs of a worker, together with shaft of sting, sting glands, and poison sack.
*BGld*, "alkaline" gland of sting; *E*, egg; *EC*, egg chamber; *GCls*, undifferentiated germ cells; *NC*, nurse chamber; *Odc*, common oviduct; *Odl*, lateral (paired) oviduct; *Ov*, ovary; *P*, lateral genital pouch; *PO*, opening of lateral pouch; *PsnGld*, poison gland of sting; *PsnSc*, poison sack; *Spt*, spermatheca; *SptDct*, spermathecal duct; *SptGld*, spermathecal gland; *Stn*, shaft of sting; *tf*, terminal filament; *Vag*, vagina; *VO*, opening of vagina; *x*, cut edge of body wall around genital openings. (*Drawing courtesy Bureau of Entomology and Plant Quarantine*)

idea has not been verified by observation. Furthermore, some investigators say that the entire penis is turned inside out, while others claim that only the end pouch is everted.

Whatever may be the facts concerning the copulatory process and the extent of the penis eversion, when the mating queen finally separates herself from the drone, only the penis bulb remains in her genital tract, the male organ having been torn apart at its weakest point between the bulb and the penis neck. The spermatozoa discharged from the bulb make their way probably by their own motion through the vagina to the mouth of the spermathecal duct, ascend the latter, and accumulate in the spermatheca itself. The movements of spermatozoa generally are guided by some kind of chemical influence. The sperm retain their vitality within the spermatheca throughout the productive life of the queen.

When an egg in the ovary is ready to be discharged, the lower end of its follicle opens and the egg passes down the oviduct into the vagina. The deserted follicle shrivels and is absorbed as the next one above takes its place, and the ovariole regains its length by growth at the upper end where the new eggs are forming. Considering the great number of ovarioles in the two ovaries of the queen bee, it is clear how eggs may be matured continuously and take their places consecutively in the vagina.

As the eggs descend the oviducts and enter the vagina they undergo the last act of their maturing process. This consists of two consecutive divisions of the egg nucleus, one of the new nuclei becoming the definitive egg nucleus, the others being absorbed. The nuclei of all cells contain small bodies known as *chromosomes*. In the female honey bee the accepted number of nuclear chromosomes is 32, in the male 16. At the first division of the egg nucleus half the chromosomes go into each newly formed nucleus, the persisting egg nucleus being thus reduced to 16 chromosomes. At the second division the chromosomes split so that 16 are retained in each nucleus. The eggs are now ready for fertilization by the spermatozoa, which are discharged upon them from the spermatheca. But only eggs that are to produce female larvae are fertilized; eggs that are to produce males are not fertilized. When a spermatozoon, containing 16 chromosomes, enters an egg through the micropyle and its nucleus unites with the egg nucleus, containing also 16 chromosomes, the fertilized egg will contain 32 chromosomes, and consequently develops into a female bee. On the other hand, an unfertilized egg remains with only 16 chromosomes in its nucleus and can develop only into a drone.

The queen evidently is able to control fertilization of the eggs in the vagina. How she does it is not known, but the discharge of the sperm appears to be regulated by a muscular apparatus in the wall of the spermathecal duct, and it is generally believed that the queen is able to withhold sperm from eggs laid in drone cells. The eggs finally are discharged from the vaginal orifice at the base of the sting. Whether the fertilized egg becomes a queen or a worker now depends on the feeding of the larva.

# XX. *Production and Uses*

IN ANCIENT TIMES beeswax was much more important than it is today because, except for the softer tallow, there were very few known waxes or waxlike substances. Honey was the only known sweet and beeswax was obtained when the combs were crushed to get the honey. Beeswax is mentioned in the Scriptures and in ancient Greek mythology. And down through the centuries—the Greek and Roman eras and the Middle Ages—beeswax was used in cosmetics and pharmaceuticals, as a modeling and sculpturing medium, in candles for furnishing light, and for many other purposes.

With the turn of the present century, other waxes and waxlike substances have come into commercial importance in this country, bringing with them a relative decline in the importance of beeswax in commerce.

From the vegetable kingdom we obtain *carnauba wax,* the hardest and most brilliant wax in nature, from a species of palm tree growing in Brazil, South America; *candelilla wax* from a Mexican desert plant; *ouricury wax* also from the leaves of a palm tree in Brazil; *bayberry wax* from the berries of the myrtle bush in this country; *Japan wax* from a species of sumac in Japan; and others of less current commercial importance including *sugar cane wax, ucuuba wax, flax wax, cotton wax, esparto wax, cauassu wax, murumuru wax,* and *palm wax.*

From the animal kingdom, in addition to beeswax, are obtained *spermaceti* from the head regions of certain whales and dolphins; *wool wax* or *lanolin* from the wool of sheep; and *Chinese insect wax* and *shellac wax,* both secreted by insects.

In the mineral kingdom *ozokerite* is mined from the ground in Utah and Austria. When refined and bleached it is known as *ceresin wax. Montan wax* is obtained in the steam distillation of lignite, and is considered by some as being semimineral and semivegetable in origin. The petroleum waxes, particularly *paraffin,* while chemically not true waxes, are waxlike and are of great commercial importance.

There also are many synthetic waxes and waxlike substances now being used in increasing amounts. These include the amorphous and microcrystalline waxes, primarily of petroleum origin; the chlorinated, sulfonated, and hydrogenated oils, fats and waxes; and the so-called synthetic

*Roy A. Grout. Production manager of Dadant & Sons. Associate editor of the *American Bee Journal.* Special studies in the production and uses of beeswax.

idea has not been verified by observation. Furthermore, some investigators say that the entire penis is turned inside out, while others claim that only the end pouch is everted.

Whatever may be the facts concerning the copulatory process and the extent of the penis eversion, when the mating queen finally separates herself from the drone, only the penis bulb remains in her genital tract, the male organ having been torn apart at its weakest point between the bulb and the penis neck. The spermatozoa discharged from the bulb make their way probably by their own motion through the vagina to the mouth of the spermathecal duct, ascend the latter, and accumulate in the spermatheca itself. The movements of spermatozoa generally are guided by some kind of chemical influence. The sperm retain their vitality within the spermatheca throughout the productive life of the queen.

When an egg in the ovary is ready to be discharged, the lower end of its follicle opens and the egg passes down the oviduct into the vagina. The deserted follicle shrivels and is absorbed as the next one above takes its place, and the ovariole regains its length by growth at the upper end where the new eggs are forming. Considering the great number of ovarioles in the two ovaries of the queen bee, it is clear how eggs may be matured continuously and take their places consecutively in the vagina.

As the eggs descend the oviducts and enter the vagina they undergo the last act of their maturing process. This consists of two consecutive divisions of the egg nucleus, one of the new nuclei becoming the definitive egg nucleus, the others being absorbed. The nuclei of all cells contain small bodies known as *chromosomes*. In the female honey bee the accepted number of nuclear chromosomes is 32, in the male 16. At the first division of the egg nucleus half the chromosomes go into each newly formed nucleus, the persisting egg nucleus being thus reduced to 16 chromosomes. At the second division the chromosomes split so that 16 are retained in each nucleus. The eggs are now ready for fertilization by the spermatozoa, which are discharged upon them from the spermatheca. But only eggs that are to produce female larvae are fertilized; eggs that are to produce males are not fertilized. When a spermatozoon, containing 16 chromosomes, enters an egg through the micropyle and its nucleus unites with the egg nucleus, containing also 16 chromosomes, the fertilized egg will contain 32 chromosomes, and consequently develops into a female bee. On the other hand, an unfertilized egg remains with only 16 chromosomes in its nucleus and can develop only into a drone.

The queen evidently is able to control fertilization of the eggs in the vagina. How she does it is not known, but the discharge of the sperm appears to be regulated by a muscular apparatus in the wall of the spermathecal duct, and it is generally believed that the queen is able to withhold sperm from eggs laid in drone cells. The eggs finally are discharged from the vaginal orifice at the base of the sting. Whether the fertilized egg becomes a queen or a worker now depends on the feeding of the larva.

# XX. *Production and Uses of Beeswax*

BY ROY A. GROUT*

IN ANCIENT TIMES beeswax was much more important than it is today because, except for the softer tallow, there were very few known waxes or waxlike substances. Honey was the only known sweet and beeswax was obtained when the combs were crushed to get the honey. Beeswax is mentioned in the Scriptures and in ancient Greek mythology. And down through the centuries—the Greek and Roman eras and the Middle Ages—beeswax was used in cosmetics and pharmaceuticals, as a modeling and sculpturing medium, in candles for furnishing light, and for many other purposes.

With the turn of the present century, other waxes and waxlike substances have come into commercial importance in this country, bringing with them a relative decline in the importance of beeswax in commerce.

From the vegetable kingdom we obtain *carnauba wax,* the hardest and most brilliant wax in nature, from a species of palm tree growing in Brazil, South America; *candelilla wax* from a Mexican desert plant; *ouricury wax* also from the leaves of a palm tree in Brazil; *bayberry wax* from the berries of the myrtle bush in this country; *Japan wax* from a species of sumac in Japan; and others of less current commercial importance including *sugar cane wax, ucuuba wax, flax wax, cotton wax, esparto wax, cauassu wax, murumuru wax,* and *palm wax.*

From the animal kingdom, in addition to beeswax, are obtained *spermaceti* from the head regions of certain whales and dolphins; *wool wax* or *lanolin* from the wool of sheep; and *Chinese insect wax* and *shellac wax,* both secreted by insects.

In the mineral kingdom *ozokerite* is mined from the ground in Utah and Austria. When refined and bleached it is known as *ceresin wax. Montan wax* is obtained in the steam distillation of lignite, and is considered by some as being semimineral and semivegetable in origin. The petroleum waxes, particularly *paraffin,* while chemically not true waxes, are waxlike and are of great commercial importance.

There also are many synthetic waxes and waxlike substances now being used in increasing amounts. These include the amorphous and microcrystalline waxes, primarily of petroleum origin; the chlorinated, sulfonated, and hydrogenated oils, fats and waxes; and the so-called synthetic

*Roy A. Grout. Production manager of Dadant & Sons. Associate editor of the *American Bee Journal.* Special studies in the production and uses of beeswax.

waxes composed of high molecular weight glycols, alcohols, stearates, and other chemical compounds.

In spite of the many waxes or waxlike substances, beeswax, the "old man" of the wax kingdom, has not lost its commercial importance.

## Amount of Beeswax Produced

It is difficult to estimate the quantity of beeswax produced in this country because a part of the production never reaches the market, being consumed in the form of comb honey, used about the farm and home, or lost in many ways. Voorhies, Todd, and Galbraith[1] stated that since 1900 the present ratio of beeswax production to the amount of honey produced is probably about one to sixty-eight (1:68), adding that future beeswax production will likely be influenced, as in the past, by changes in production methods. In more recent years, the production of beeswax has approximated 2 pounds of beeswax to 100 pounds of honey produced, a ratio of 1:50. Statistics issued by the U.S.D.A., Bureau of Agricultural Economics for 1947 give the production of beeswax as 4,492,000 pounds and the production of honey as 228,162,000 pounds, a ratio of approximately 1:50.

## Amount of Beeswax Imported

It is of interest to point out that this country imports more beeswax annually than it produces; over half, usually about four-sevenths, of the beeswax consumed comes from abroad. Brazil and Chile in South America, Cuba and the West Indies, Mexico and Central America, and Africa, Madagascar, and Egypt are the principal countries of origin. Many other countries of the world produce beeswax but in most of them, as in our own, it is consumed at home. With but few exceptions, this beeswax is produced by different races and strains of the honey bee, *Apis mellifera* L.

According to Lewkowitsch,[2] other species of *Apis* and *Trigona* secrete beeswax. East Indian beeswax contains some proportion of the wax obtained from the Indian Dammar bee, *Trigona laeviceps,* Smith. In the Philippines beeswax is obtained from *Apis zonata, A. dorsata,* and *A. indica.* These species, as well as *A. florea,* also produce beeswax in China, Japan, and India. Since this wax has different physical and chemical properties from that produced by our honey bees, it cannot be considered pure beeswax according to United States standards. Nevertheless, it cannot be denied that it is a pure product of a bee. Only a small quantity of this type of beeswax reaches this country.

---

[1]Voorhies, Edwin C., Frank E. Todd, and J. K. Galbraith. 1933. Economic aspects of the bee industry. *Calif. Agr. Exp. Sta. Bull.* 555. p. 84.

[2]Lewkowitsch, J. 1921. *Chemical Technology and Analysis of Oils, Fats, and Waxes.* 6th ed. London. Macmillan & Co., Ltd. Vol. II. pp. 906–932.

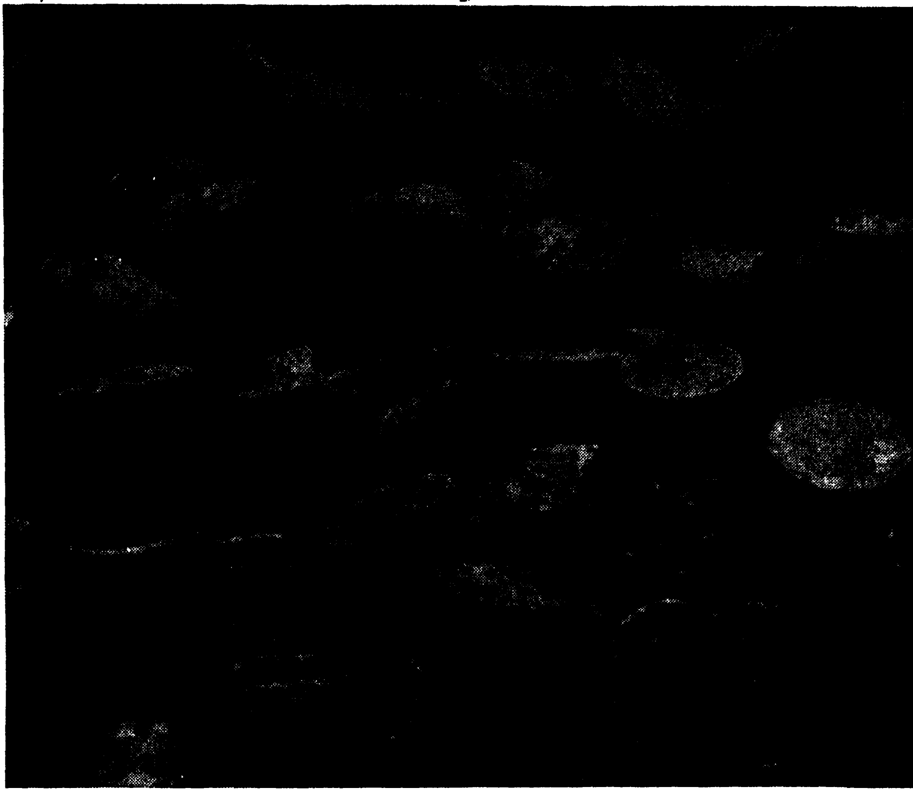


FIGURE 257. Crude beeswax in cake form ready to be trucked to market.

## Sources of Crude Beeswax

The production of beeswax can be considered only secondary to the production of honey by beekeepers. The amount produced is many times less than the amount of honey obtained. Often it is referred to as the "by-product" of honey production. Thus methods of producing, collecting, and preparing beeswax for the market must be co-ordinated with the production of honey.

The beekeeper's sources of beeswax are cappings, bits of comb, burr combs, brace combs, frame and hive scrapings, and combs which have become unfit for use for various reasons. Cappings yield from 10 to 12 pounds of beeswax per 1,000 pounds of extracted honey. When deep cappings are cut, the yield of wax may amount to 15 and even 18 pounds of beeswax. The bits of comb removed during the work with the bees, the burr combs, brace combs, and hive and frame scrapings, if diligently collected and carefully saved, can amount to approximately a half pound of beeswax per colony each year. The amount of beeswax obtained from

unsuitable combs varies with the number of combs available, their age, and their condition. It usually is stated that a set of ten combs of the Langstroth size will yield about 2½ pounds of beeswax.

Manufacturers and distributors of bee supplies have become the collectors of the majority of domestic beeswax. A certain amount is collected by wax dealers and bleachers of beeswax, while the remainder is either sold to industrial consumers, used about the farm and home, or lost in various ways. Crude beeswax is marketed in cakes of different sizes and shapes, of varying color and odor, and of many degrees of cleanliness (Fig. 257). It is necessary to refine crude beeswax for industrial use or for resale.

## Cappings

Cappings are obtained when the surface of combs of honey are cut away previous to extracting the honey. The honey which is removed with the cappings is separated from the wax by draining by gravity, centrifugal force, or pressure, or by melting the cappings in some type of cappings melter. A few operators have devised methods whereby the bees dry or remove the honey from the cappings before they are melted.

When cappings are drained, some honey still remains with them. This honey may be washed out with warm water and the sweet water used for making vinegar. If the cappings are not washed, an excess amount of water should be used when melting them in hot water. If too little water is used, a good proportion of the wax on congealing will be found to be granular in appearance, not solid like the rest of the cake. While this granular material is essentially beeswax, it is very difficult to get it to return to the form of solid beeswax by further melting over water. Heating with dry heat seems to be the best method of returning it to a form which will congeal into a solid cake.

When cappings are melted in a cappings melter, a solid cake of wax is obtained. These cakes are usually sticky with honey and should either be washed, after scraping the sediment from their bottoms, or remelted over an excess of water in order to clean the beeswax further. The scrapings from the bottoms of the cakes should not be discarded as this material is rich in beeswax, and should be rendered again with other beeswax refuse. Only new combs should be melted with cappings. Burr combs, brace combs, frame and hive scrapings, and unsuitable combs should be kept separate and melted into cake form in a different manner. The best grades of light, lemon-colored beeswax are obtained from cappings. The wax is slightly higher in melting point than crude beeswax from comb sources, and usually commands a higher price on the market. For additional information in regard to methods of handling cappings, see Chapter XI, "Extracting the Honey Crop." For information concerning the making of honey vinegar, see Chapter XV, entitled "Honey."

## Bits of Comb

Especially during the honeyflow, many bits of comb are scraped from the top bars, or removed from other places in the hive, and usually placed in front of the entrance for the bees to clean them of nectar and honey. This may be done when disease is not prevalent or when there is little likelihood of robbing. Before leaving the apiary, these bits of comb should be collected and either placed in a solar wax extractor or in containers for future melting and protected from the ravages of the wax moth. When disease is prevalent or robbing is likely to occur, the bits of comb material should not be left exposed. At times, they may be left in parts of the hive for the bees to clean, or they may be collected as they are.

The solar wax extractor is useful to any beekeeper (Fig. 258), and is simple and economical to construct. It should be bee tight and ample in size to meet the beekeeper's requirements. Usually it consists of a long narrow box, covered on top by glass and tightly made in order to hold the sun's heat. Inside is a sheet of metal upon which the comb material is placed. It is slightly inclined to permit the melting beeswax to run down into a pan. For best results it is placed facing the south, so that it will receive the maximum hours of sunshine. Not only is the solar wax extractor useful in melting the accumulation of bits of comb from day to day, but it also may be used in warmer climates for melting cappings, super combs, and even brood combs which have become darkened through long use in the brood nest. The refuse or slumgum which accumulates in the solar should be removed regularly, saved, and rendered with old combs or other refuse materials.

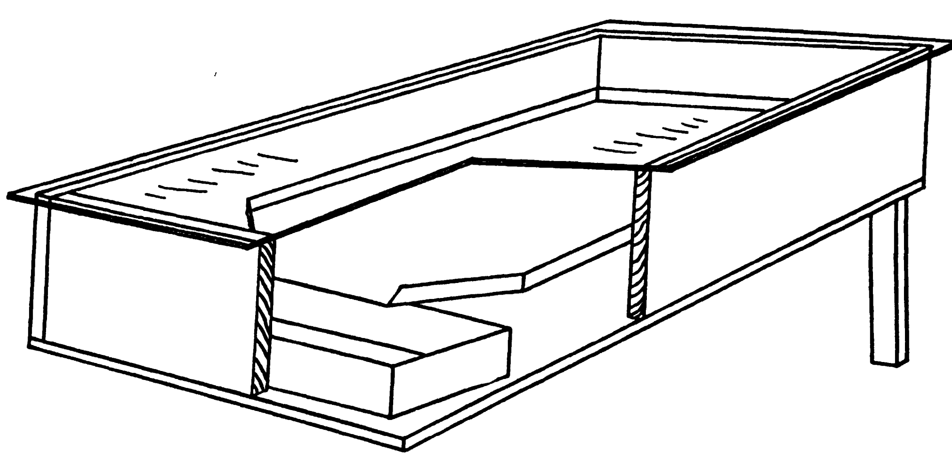


Figure 258. Diagram of a solar wax extractor—a useful piece of equipment to any beekeeper for melting many bits of wax combs and cappings.

## Old Combs

Some beeswax can be recovered from old combs by melting them in hot water or in a hot box, but the remaining refuse material still contains a substantial amount of beeswax. A common method is to soak the combs in warm water for a day or more, and then to place them in a sack and submerge in boiling water with no further treatment than to occasionally poke, squeeze, and turn the sack to aid in the recovery of the beeswax. This method is likely to be inefficient.

In practice today are two extensively used methods of recovering wax from old or unsuitable combs: the hot-water press and the steamer.

The *hot-water press* was developed in Germany and sometimes is referred to as the German press. Hershiser later developed the hot-water press that is in common use today. The size of the press should be about 20 by 20 by 20 inches if a capacity of about 75 pounds of beeswax per day (yielded from about 300 combs) is desired. A press measuring 16 inches each way is ample in size for the small beekeeper. There is an opening in the bottom for a drain and another for the introduction of hot water. Steam for heating the water is introduced at the bottom of the press.

It is well to break up the combs and to soak the material in warm water for 24 hours prior to the pressing operation. The pollen and some of the other foreign material will absorb water which results in these materials absorbing less wax when pressed and, consequently, a greater yield of wax. Some prefer to let the comb material soak in water until fermentation sets in and claim a greater yield of wax and a clearer product. The comb material can be left thus for months without injury to the wax and pressed at the end of the season.

The comb material then is placed in burlap and the sides folded over and fastened to hold the comb material under the pressure of the screw of the press. This commonly is called a "cheese." Usually two wood-slatted mats are placed between three cheeses. The water is heated to the boiling point and gentle boiling maintained. Pressure is applied intermittently by means of the screw to press the melted wax from the interior of the cheeses. At the end of the operation, the steam is shut off and the water level raised to float the beeswax out of the opening toward the top of the press and into molds.

Some beekeepers melt the combs in a tank of boiling water before proceeding to the pressing operation. The frames containing the combs can be placed directly in the tank and are cleaned in this manner. The beeswax which rises to the surface can be dipped off into molds, or made into cheeses along with the other material which is still high in beeswax content.

The *steamer* has come into use more recently and, if properly constructed and operated, gives sufficiently good practical results to warrant consideration. Steam either is introduced into a closed tank below the

comb material, or several inches of water in the bottom are heated, the steam rising among the comb material. A low steam pressure of several pounds is maintained by weighting the lid to keep the steamer closed as tightly as possible. The frames containing the combs, as well as complete hive bodies of combs, may be placed in racks in the steamer. Because of this, the steamer usually is much larger than the hot-water press.

The combs are suspended above the bottom on a series of screens which catch and hold the refuse material. As the combs melt, the beeswax drips through the screens and is drawn off at the bottom from time to time with the condensed steam. While not considered as efficient as the hot-water press, its comparable efficiency is high. It also can be used for cleaning frames and sterilizing equipment.

Beekeepers who do not have means for efficient rendering of combs can melt them in hot water, collecting all the material and allowing it to congeal in containers until they have a sufficient amount for shipment to a rendering center. Melted-down comb material is safe from moth damage, and the bulk of the material is reduced for convenience in shipping.

### Slumgum

Slumgum is the material remaining after some melting treatment has been performed on comb material. It may be more or less rich in beeswax and is usually dark brown or almost black in color. Unless the beekeeper has a good hot-water press and knows how to use it properly, he will not get all the wax out of his comb material. Certain rendering firms guarantee the freight on a minimum shipment of slumgum, enabling the beekeeper to determine the efficiency of his rendering method.

Even the best commercial methods of rendering beeswax from old combs result in a refuse which still contains some beeswax. The only known way to recover this last bit of beeswax is by solvents, but results in a wax not suitable for marketing because the solvents extract the resins and gums from pollen, propolis, and other sources along with the beeswax. The resulting product is lower in melting point, softer, more sticky, and otherwise not like pure beeswax.

## Preparing Crude Beeswax for the Market

According to Bisson[3] and his associates, wax scales are white in color and fairly uniform in their physical and chemical characteristics. But, from the time the worker bees begin to manipulate the scales in comb construction, the beeswax is changed by contact with pollen, propolis, honey, dust, and brood food and its decomposition products. Propolis and pollen are probably the most important contaminants and sources of color in beeswax.

---

[3]Bisson, Charles S., George H. Vansell, and Walter B. Dye. 1940. Investigations on the physical and chemical properties of beeswax. *U.S.D.A. Tech. Bull.* 716.

When the cappings and combs are melted, further changes take place when the liquid beeswax comes into contact with the above materials. Crude beeswax often contains parts of bees, dirt, straw, leaves, rags and many other foreign materials.

It is considered good practice to melt beeswax in an excess of soft water. If the water is hard, it is advisable to acidulate it with one tablespoon of vinegar for each gallon of water. Strong acids, like sulfuric acid, should not be used because they are very dangerous if not properly handled and are likely to be injurious to the wax. The wax should be boiled gently; prolonged boiling will result in damage to the beeswax.

When beeswax is melted in the absence of water, discoloration ordinarily occurs when the temperature exceeds 185° F. Live steam should never be directed against beeswax in a steamer or other melting device because it results in a partial saponification, harmful to beeswax. If beeswax is melted over an open flame, it should always be done outdoors. Disastrous fires have resulted when beeswax was melted in this manner inside honey houses.

Tanks used in melting beeswax preferably should be made of tinned copper, heavily coated tinned iron known as "dairy tin," stainless steel, or aluminum. Bisson and his associates demonstrated that beeswax is discolored very little, if any, by glass, stainless steel, aluminum, nickel, and platinum. Monel metal, iron and zinc discolored beeswax and made it more brown in color, while brass and copper caused it to become green in color. Most rendering equipment used by the beekeeper is made of galvanized iron which serves all practical purposes when beeswax is melted in the presence of water. Rough iron tanks should not be used because they rapidly discolor beeswax.

The containers in which the cakes of beeswax are molded should be flaring to facilitate removing the congealed cakes. An inch or two of hot water in the bottom of the molds will aid in removing the cakes. The bottoms of the cakes of beeswax should be scraped to remove the material which has settled. These scrapings, although they do not resemble beeswax in some cases, should be saved and rendered with additional lots of combs because they contain much beeswax.

## Refining Beeswax

Beeswax is refined by melting and gentle boiling over water in large tanks where it is permitted to stand until the heavier impurities have settled to the bottom of the liquid wax or into the water layer (Fig. 259). The ligher impurities rise to the surface and are skimmed off during the boiling. Some refiners use chemicals to speed the refining process and to improve the color, particularly of darker grades of beeswax. Sometimes repeated washing or rinsing with hot water is employed until the liquid beeswax is clear. Beeswax also has been refined by centrifuging.

FIGURE 259. Cakes of fully refined pure beeswax, ready for manufacturing processes.

The United States Dispensatory[4] defines yellow wax (refined) as "the purified honey comb of the bee, *Apis mellifera,* Linné—(Family *Apidae*)." It is described further as a solid, varying in color from yellow to grayish brown. It has an agreeable honeylike odor, and a faint characteristic taste. The specific gravity is 0.951 to 0.960 at 25° C. (77° F.). The melting point is 62° to 64° C. (143.6° to 147.2° F.). It is somewhat brittle when cold, and when broken presents a dull, granular, noncrystalline fracture. By the heat of the hand, it becomes plastic. Yellow wax is insoluble in water, sparingly soluble in cold alcohol, completely soluble in ether, chloroform, and in fixed and volatile oils, partly soluble in cold benzene or in carbon disulfide, and completely soluble in these liquids at about 30° C. (86° F.).

Further tests are described for the presence of fats, fatty acids, Japan wax, or rosin. The acid value is not less than 18 nor more than 24. The ester value is not less than 72 nor more than 77. A test for adulteration with carnauba wax based on the work of Watson,[5] which has been accepted qualitatively by the U. S. Pharmacopoeia, also is given. By great heat it is partly volatilized and partly decomposed; and, when flame is applied to its vapors, it takes flame and burns with a clear, bright light. It is not affected by acids at ordinary room temperatures, but is converted into a black mass when boiled with concentrated sulfuric acid.

Commercial refined beeswax is light yellowish brown to orange brown in color and of uniform quality. It is usually marketed in the form of 20-pound slabs, 1-pound cakes, and small shapes weighing approximately 1 ounce.

---

[4]1937. *United States Dispensatory.* 22nd Centennial ed. Philadelphia, Pa. Lippincott Co. pp. 309–312.

[5]Watson, Lloyd R. 1930. The detection of carnauba wax in beeswax. *Amer. Bee Journal* 70:118.

## Bleaching Beeswax

United States beeswax does not bleach readily either by chemical means or when exposed to the sun's rays. Bleachable grades consumed in this country largely comprise the yellow grades of beeswax from Brazil, Chile, Cuba, and Egypt. Usually the beeswax is given some chemical treatment to refine and partially bleach it, and the process is completed by exposing the wax in the form of fine shreds to the sun's rays. Common bleaching chemicals include the bichromates, permanganates, peroxides, and chlorine compounds. Beeswax also may be filtered to clean it and to lighten its color. Diatomaceous earth and carbons are added to the liquid wax, usually after a preliminary refining, then agitated and filtered. Bleached beeswax is sold in the form of large slabs, pound cakes, discs weighing from 2 to 3 ounces, and small shapes weighing 1 ounce each.

## Propolis

Propolis is a resinous material gathered by bees from the exudations of the buds of certain trees and other vegetative sources. Propolis, as seen in the beehive, usually is admixed with beeswax and is not difficult to recognize due to its brown and usually greenish color. Being of sticky or gummy consistency, the bees do not form it into the shape of a comb. It is used to fill cracks, reduce openings, cover objectionable things inside the hive, and for a number of other purposes. Propolis is objectionable to the beekeeper because it makes removal of frames more difficult and sticks to the hands in warm weather. It may be removed by washing with alcohol or other solvent.

Propolis is a natural contaminant of beeswax. Because some of the resins of propolis are soluble in liquid beeswax, whenever possible, propolis should not be collected with frame and hive scrapings. When this is not practical, the scrapings should be kept separate from all other forms of beeswax and melted separately. Much propolis lowers the melting point, makes the beeswax softer and more sticky, and changes the physical and chemical characteristics. For further information on propolis, see Chapter IV, "Activities of Honey Bees."

In rendering comb material which is high in propolis content, a large amount of propolis settles to the bottom of the container while the beeswax rises to the surface. On cooling, this portion of the propolis is hard, brittle, and otherwise physically unlike the material gathered by the bees or used by them in the hive.

The modern beekeeper does not collect or save propolis. But it is of interest to point out that the old Italian violin varnish, as used by Stradivarius and other noted makers of Cremona, contained propolis from the poplar as the principal ingredient.

## Bloom on Beeswax

On standing for a period of time, particularly in cold weather, a powdery deposit forms on the surface of beeswax. It sometimes is referred to by beekeepers as mildew or mold, although it resembles neither one. Little is understood concerning the cause of bloom or its composition. It forms on beeswax before melting and reappears on beeswax products after processing. If it is rubbed off a cake of beeswax, it may appear again. According to Vansell and Bisson,[6] bloom melts at 102° F. which is approximately 40° below the melting point of beeswax.

## Uses of Beeswax

### Cosmetics

The largest consumer of beeswax in this country is the cosmetic industry (Fig. 260). Bleached beeswax is the ingredient which causes the white, pearly emulsion of all typical cold creams. Many other types of creams,

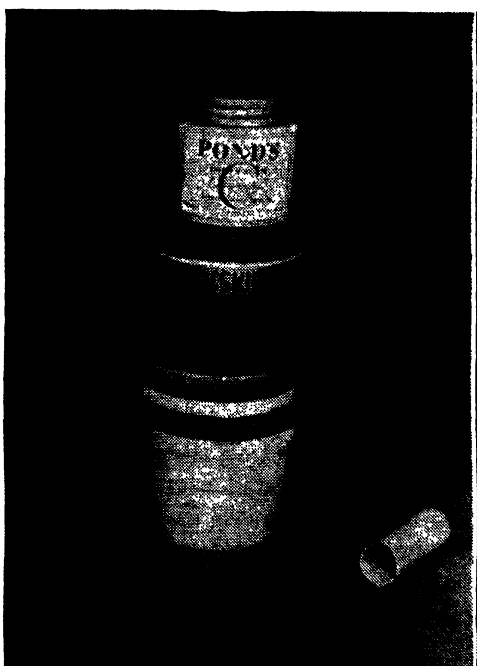


FIGURE 260. Cosmetics of many kinds contain pure beeswax. Bleached beeswax is responsible for the white pearly emulsion of cold creams.

FIGURE 261. Church candles made from pure beeswax—a display showing the various sizes and types used by the Catholic Church.

[6] Vansell, George H. and C. S. Bisson. 1940. Brief presentation of the characteristics, contaminants, processing, and uses of beeswax. *Calif. Agr. Exp. Sta. Circ.* E-495.

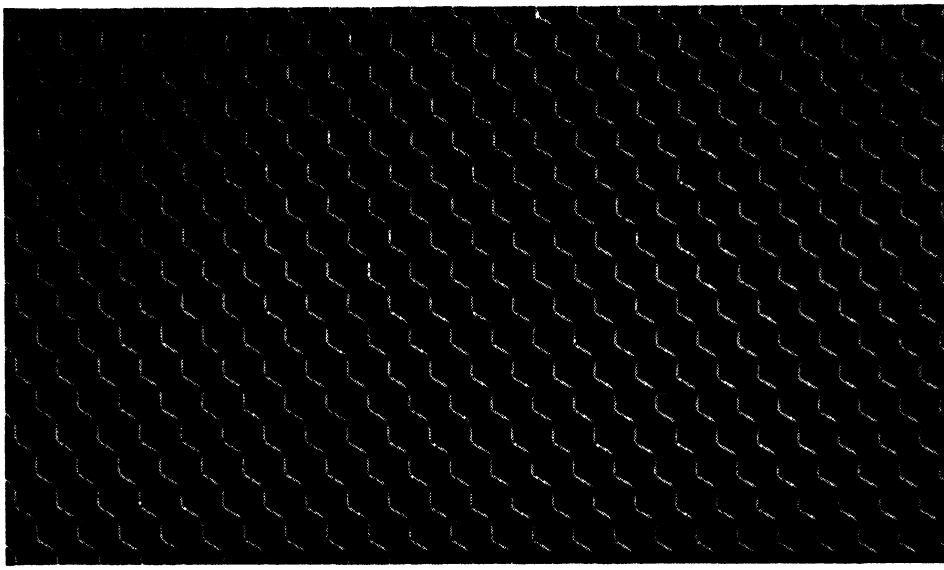


FIGURE 262. Comb foundation—the only use of beeswax in which it is not lost, but returns to market later as pure beeswax.

ointments, lotions, lipsticks, pomades, rouges, and other items contain beeswax in their formulas. Undoubtedly the expansion of this industry in the past several decades has taken up the slack of a decreasing demand for beeswax on the part of other industries which turned to materials usually lower in price.

### CHURCH CANDLES

Probably the next largest use of beeswax is in the production of church candles (Fig. 261). The Jewish, Greek Catholic, and certain other faiths use beeswax candles to some extent, but the chief user is the Roman Orthodox Catholic Church. In its antiquity the Church sought the purest sources of light for its religious ceremonies, selecting beeswax and olive oil. Originally they required that the candles burned on the altar during the services of Mass and the Benediction of the Blessed Sacrament be of pure beeswax. In the earlier development of the Church in this country, pure beeswax candles could not always be obtained and allowances had to be made, resulting in a ruling that the candles must be of greater part beeswax. Today most candle manufacturers make 51 per cent, 60 per cent, and pure beeswax candles.

### COMB FOUNDATION

Since the beginning of the present century, it has been a recognized beekeeping practice to use full sheets of foundation made from pure beeswax (Fig. 262). This is the only field of use of beeswax in which it is not consumed or lost. When the combs become unsuitable for further use in

the beehive, they are melted by the beekeeper and returned to the market as pure beeswax. In a way this is the most important use of beeswax because pure beeswax foundation used in the hive becomes the birthplace of more beeswax.

### Other Major Uses

The pharmaceutical industry uses beeswax in the preparation of salves, ointments, cerates, camphor ices, pomades, sticky wax, and like preparations. The dental trade uses beeswax in the form of impression wax, base plate wax, and in other wax compounds. Beeswax is used in foundries in the form of wax fillets for rounding the corners of small patterns, in the form of sheets of varying thicknesses, as an ingredient of modeling compounds, and in the "lost wax" process for producing precision castings.

Polishes for floors, furniture, stoves, shoes, leather, and other items contain beeswax in many of their formulas. In this field of use, beeswax largely has been replaced by carnauba wax, from which polishes are made that will dry to a bright luster without buffing or polishing. While there is evidence to indicate that polishes made from beeswax give greater service and protection, the convenience of application without the necessity of buffing has met with popularity.

Formerly quantities of beeswax were used in electrical insulation. Beeswax still finds uses in electrical embedding compounds, but its use largely has been replaced by resins and waxes, usually lower in cost. In general, beeswax is used in many ways for waterproofing, protection, and beautification.

### Compiled List of Uses of Beeswax

A. Adhesive compositions, ingredient of—
  1. Adhesive for wigs and masks
  2. Adhesive for setting bristles in brushes
  3. Adhesive for sealing closet bowls
  4. Adhering metal to glass and glass to glass
  5. Electrical and chemical cement

B. Candles
  1. Raw material in making candles
  2. Ingredient of—
    a. Liturgical candles for use in the church
    b. Nonrubrical candles containing from 15% to 35% beeswax
    c. Sanctuary lights—contain up to 51% beeswax
    d. Candle decorations

C. Comb foundation
  1. Brood foundation
  2. Thin surplus foundation
    a. Bulk comb honey
    b. Comb honey

D. Cosmetics—usually in the bleached form as an ingredient of—
   1. Actor's grease paint
   2. Camouflage creams and ointments
   3. Cleansing creams
   4. Cold creams
   5. Eyebrow pencils
   6. Lip pomades
   7. Lipsticks
   8. Massage creams
   9. Moustache wax
   10. Paste rouge
   11. Theatrical cream
E. Crayons, ingredient of—
   1. Drawing pastels
   2. Grease pencils
   3. Lithographic crayons
   4. Wax crayons
F. Dental purposes
   1. Evan's cement
   2. Horsley's wax
   3. Impression wax
   4. Pink base plate wax
   5. Sticky wax
   6. Temporary tooth filler
   7. Toothache gum
G. Electrical purposes, ingredient of—
   1. Filler for transformers and terminal boxes
   2. Insulating compositions for various purposes
   3. Insulating agent in making cables and electrical apparatus
H. Food, ingredient of—
   1. Artificial foundation of comb honey
   2. Chewing gum
   3. Compositions for coating candies
   4. Compositions for decorating fancy foods
I. Ink ingredient
   1. Lithographic inks
   2. Offset and nonoffset compounds
   3. Printing inks
   4. Stamping inks
   5. Transfer inks
   6. Writing inks
J. Leather, ingredient of—
   1. Dressing compositions
   2. Finishing preparations
   3. Various polishes
K. Metallurgical purposes, ingredient of—
   1. Coatings on ammunition and shells
   2. Compositions for preventing rust and corrosions of acids, alkalies, and other chemicals

3. Electroplating compositions
4. In shell loading
5. "Lost wax" process of Benvenuto Cellini for casting statuary in metal
6. "Lost wax" process applied to industrial castings
7. Protective agent in making acid etchings
8. Soap solutions for drawing and stamping metals
9. Waterproof coating to prevent salt water corrosion

L. Miscellaneous uses—
1. Basketball molding
2. Cartridge wax and grease
3. Composition for minimizing shrinkage of wood
4. Composition for polishing and cleaning wood or rubber
5. Foundry pattern making—
    a. Modeling wax
    b. Thin wax sheets
    c. Wax fillets
6. Gilders' wax
7. Grafting wax
8. Imitation fruits and flowers
9. Ironing wax
10. Modeling wax
11. Polishing telescopic lenses
12. Poultry—for removing feathers
13. Production of acid bottles
14. Sealing wax
15. Ski wax
16. Snow shoe wax
17. Substitute for paraffin in waxing paper
18. Waterproofing agent or ingredient of—
    a. Asbestos compositions
    b. Coatings for brick and stone
    c. Hat straw
    d. Ingredient of artificial stone
    e. Porous building materials
    f. Straw board
19. Waxing archers' bow strings
20. Waxing threads in sewing
21. Wax putty for stopping leaks in casks
22. Wax soaps

M. Oils and fats, admixture for special lubricating purposes
1. Axle grease
2. Special lubricants
3. Various gun lubricants

N. Paints and varnishes, ingredient of—
1. Antifouling paints
2. Lacquers for flexible materials
3. Paint and varnish removers
4. Preparations containing dry colors
5. Various paint mixtures

6. Varnishes
7. Wood fillers

O. Paper, ingredient of—
1. Coating composition for washable wallpaper
2. Compositions for manufacturing carbon paper
3. Emulsified sizing preparations
4. Preparations for waxing paper
5. Sizing for high-gloss paper
6. Waterproofing compositions

P. Pharmaceutical preparations, ingredient of—
1. Almond balls
2. Brushless shaving cream
3. Camphor ice
4. Cerates of various types
5. Depilators
6. Hair restorers
7. Oxyeroceum plaster
8. Pomades and "hair straighteners"
9. Pomatum for chapped lips

Q. Polishing and cleaning preparations, ingredient of—
1. Automobile polishes
2. Compositions for coloring and polishing wood
3. Floor oils and waxes
4. Liquid floor wax
5. Polishes for automobile tires
6. Powdered wax for dance floors
7. Preparations for cleaning and polishing furniture
8. Shoe creams, pastes and polishes
9. Various compositions for cleaning and polishing floors

R. Printing, ingredient of—
1. Acid proof coatings for plates in electrotyping
2. Matrices in galvanoplastic work
3. Process material in—
   a. Electrotypers' wax
   b. Lithography
   c. Photoengraving
   d. Process engraving

S. Textiles, ingredient of—
1. Assisting agent in stretching cellulose acetate filaments
2. Compositions used for finishing
3. Compositions used for sizing
4. Compositions used in the manufacture of waxed cloth
5. Impregnating and coating agents
6. Various emulsified dressings
7. Various waterproofing compositions
8. Waterproofing agent in treating yarns and fabrics
9. Waterproofing canvas
10. Waterproofing cellulose fibers
11. Waterproofing threads for shoe and harness making

# XXI. *The Production of Queens and Package Bees*

BY M. G. DADANT*

A LARGE NUMBER of bees of proper age at the time of the honey-flow is necessary to assure a maximum crop of honey. In order to have them, the colony must be headed by a good prolific queen. The wisdom of frequent requeening of productive colonies to provide a larger field force and to reduce swarming has been demonstrated. Intensive honey production and the trucking of bees from one flow to another, has meant a continuous demand on the queen for heavy egg laying, thus depleting her egg reserves more rapidly. So we find that requeening of colonies at least every 2 years is recommended. These queens and any others whose productivity is not up to standard, or whose progeny is cross or otherwise undesirable, should be replaced.

Other colonies become queenless through the death of their queens and young queens should be available to replace them or the time and effort required to supersede them may detract from the production of honey. Also, a supply of young queens is needed in making artificial divisions for replacement or for increase.

## Queens Produced in Nature

In nature, queens are raised by the worker bees whenever the colony is deprived of its queen through accidental loss or other means, providing they have worker eggs or very young larvae present in the hive. If drones are available and the weather permits the young queen to mate successfully, she then becomes the mother of the colony. When a queen becomes old, or fails for other reasons to maintain a sufficient number of worker bees, the bees then rear a new queen to supersede her. Under swarm impulse, queens may be reared for the parent colony as well as for after-swarms (see Chapter III, "The Honey-Bee Colony—Life History," and Chapter IX, "Common Practices in Management").

Many believe that the best queens are reared under the swarm impulse because the colony then has an abundance of pollen and honey,

*Maurice G. Dadant. Business manager of the *American Bee Journal.* Author of *Outapiaries* and many articles on beekeeping. Manufacturer of beekeepers' supplies.

and a large number of nurse bees to care for the larvae, thus producing vigorous, healthy queens. Others maintain that queens reared under the supersedure impulse are superior because the queen cells, fewer in number, are larger and apparently more carefully prepared and nourished. In either case, satisfactory progeny may be expected only when the colony is headed by good breeding stock, and the queen's mating occurs with a drone of good antecedents.

Queen cells which have been raised naturally, either under the swarming or supersedure impulse, may be used by the beekeeper to requeen colonies from which the old queen has been removed. They also may be placed in nuclei to be cared for until the queen emerges and mates, in the same way as queen cells which the bees have been induced to build under artificial queen-rearing methods.

These queen cells usually are removed from the parent colony some time after they have been sealed. A section of the comb, about an inch square containing the cell, is cut out and fitted into a similar place provided in a comb in the brood nest of a colony, or a nucleus, to which it is to be introduced. In warm weather, such cells may be fastened to the bottom of the brood comb, or even inserted between the top bars of two of the brood frames. In any case, extreme care should be taken in handling the "ripe" cells, guarding against undue jarring or chilling which might impair the quality of the emerging queen. Sometimes, these cells are placed in wire cell protectors until the queen emerges to prevent possible destruction by the bees.

Snelgrove[1] suggests 16 different methods by which queen cells reared under natural conditions may be utilized. Recognizing what is generally known; namely, that the best queens are produced from larvae 18 to 36 hours old, he suggests that when cells are raised by removing the queen from a colony, the first sealed cells should be destroyed, inasmuch as they are likely to contain older larvae, and that the newer, unsealed cells should be allowed to mature. This insures queens originating from larvae of the proper age.

Unless carefully and expertly done, home requeening methods are apt to accomplish only half their purpose because, too often, both the selection of high grade colonies for the raising of the queen cells and care in assuring a maximum of superior drones may be neglected.

## Home Methods of Queen Rearing

The circumstances of each beekeeper will dictate whether he should buy his queens from an experienced queen breeder or devote his time and equipment to rearing them. It must be remembered that queen rearing requires an extensive knowledge of bee behavior, and care-

[1]Snelgrove, L. E. 1946. *Queen Rearing*. Bleadon, England. I. A. Snelgrove.

ful and precise methods. As previously stated, the queen breeder must have a source of good breeding stock, both for the selection of larvae as potential queens and for drones for fertilizing the virgin queens. He must expect losses of queens due to inclement weather when the queens may be mating. He should be aware of the possibility of his location not making it feasible to rear queens early in spring or late in fall when they may be needed.

In the rearing of queens, it is important to select two or more colonies in the apiary; at least one for the production of drones, and several others for furnishing the larvae from which the queens are to be raised. The colony selected for furnishing the drones should contain sufficient drone comb to insure an ample supply of them. Other colonies should be furnished with drone traps. Queen breeders generally try to requeen, with selected stock, all neighboring colonies within flight range of the queen mating yard to insure best mating results. The colonies selected for furnishing drones, as well as those selected for supplying the larvae from which the queens are to be raised, should be the best in the apiary from all standpoints, and amply provisioned with stores of honey and pollen.

### Cells by the Miller Plan*

Dr. C. C. Miller[2] described a method of raising queen cells for home use which he considered just as good as any artificial method for a moderate number of cells. We can do no better than to quote from his original instructions for securing good queen cells.

> Into an empty brood-frame, at a distance of 2 or 3 inches from each end, fasten a starter of foundation about 2 inches wide at the top, and coming down to a point within an inch or two of the bottom-bar. Put it in the hive containing your best queen. To avoid having it filled with dronecomb, take out of the hive, either for a few days or permanently, all but two frames of brood, and put your empty frame between these two. In a week or so you will find this frame half filled with beautiful virgin comb such as bees delight to use for queen-cells. It will contain young brood with an outer margin of eggs. Trim away with a sharp knife all the outer edge of the comb which contains eggs, except perhaps, a very few eggs next to the youngest brood. This, you will see, is very simple. Any bee-keeper can do it the first time trying, and it is all that is necessary to take the place of preparing artificial cells.
>
> Now put this "queen-cell stuff," if I may thus call the prepared frame, into the middle of a very strong colony from which the queen has been removed. The bees will do the rest, and you will have as good cells as you can possibly have with any kind of artificial cells. You may think bees will start "wild cells" on their own comb. They won't; at least never any to amount to anything, and, of course, you needn't use those. The soft, new comb with abundant room at the edge, for cells, is so much more to their taste that it has a practical monopoly of all the cells started. In about 10 days the sealed cells are ready to be cut out and used wherever desired.

*Another simple method of raising queen cells, used by Dr. Miller is discussed later under "Starting the Queen Cells" in this chapter.

[2]Miller, C. C. 1912. How best queen-cells can be secured. *Amer. Bee Jour.* 52(8):243.

Naturally the beekeeper will have his colonies prepared to receive these queen cells. Nine days after furnishing the partly built comb to the queenless colony (Fig. 263), count the number of queen cells that have been constructed, remembering that if it is desired to requeen the parent colony one cell must be left. On the same day, destroy the queen cells in the colonies you expect to requeen, or remove the queens from those which are still queenright. You can make nuclei to receive the balance of the cells in excess of what you need immediately.

The following day, with a sharp knife remove each queen cell from the comb (Fig. 264), cutting away a square or uniform shape of the wax comb. The piece of comb with the attached queen cell now is ready to

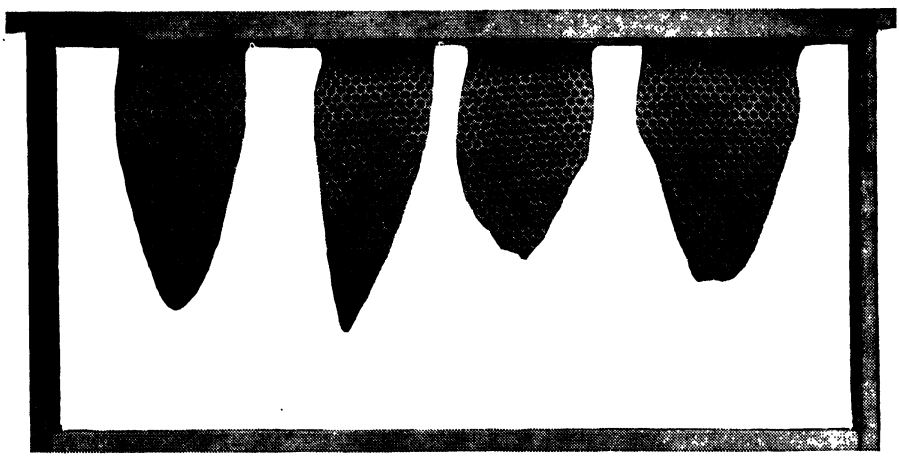


FIGURE 263. The partly built combs containing eggs and young larvae. The two combs on the right have been cut along the edges leaving young larvae for queen cells.

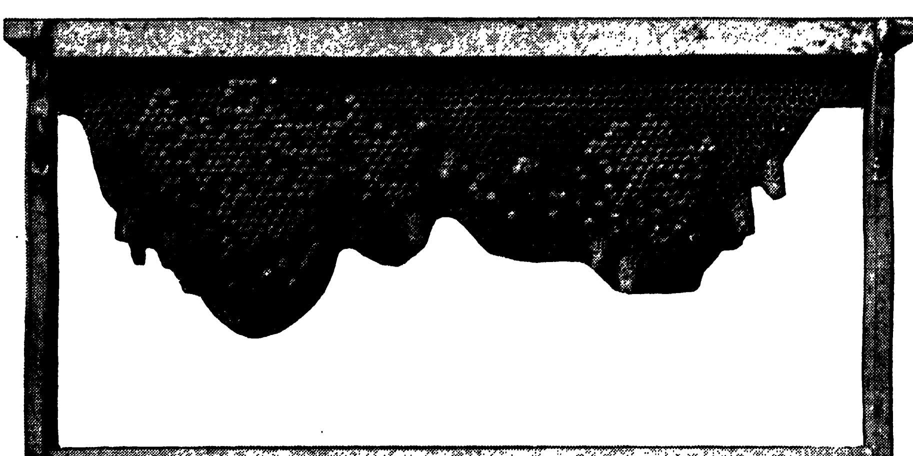


FIGURE 264. This is the same comb after queen cells have been constructed along its edge. The bees also are using the center of the comb for brood rearing.

be fitted into an opening carefully prepared for it, preferably in the center of a comb of emerging brood of one of the colonies that is to be requeened. If the weather is warm and the colony is strong, the cell simply may be inserted between the brood combs. The cell should always be placed in its natural position with the point downward.

A day or two after the introduction of the cell, the colony should be examined, and those cells which have not been accepted should be replaced from the next supply. A cell which has not been accepted will be found torn open on the side, instead of being open at the lower end.

### The Case Method*

Into the brood nest of your selected colony, insert a new comb, or a sheet of comb foundation in a frame. When the queen has laid this full of eggs, and before the larvae are more than a few days old, remove the comb to a warm place to avoid chilling and lay it flat on a worktable with the side containing the most desirable young larvae uppermost. Crush or destroy two rows of cells and larvae, leaving the third row intact for the full length of the comb. Similarly, save every third row of cells and the larvae on the entire side of the frame. Next, destroy two out of every three cells and their larvae in the remaining rows, leaving the third cell intact. Thus, there are eggs or young larvae sufficiently removed from each other so that ensuing queen cells will be far enough apart that they can be readily cut from the comb without damage to adjoining cells.

The prepared comb now is returned to the cell-raising colony, but, instead of placing it in the usual position between the other combs in the hive body, it is laid flat, horizontally, over the top of the brood combs. Further, it is raised about an inch by means of wood blocks placed under the prepared frame. All is carefully packed to avoid chilling and left until the cells are sealed and ready to be removed. With favorable weather under ideal conditions, a large number of cells may thus be raised preparatory to requeening operations.

### The Alley Method[3]

From a new worker comb filled with hatching eggs, a strip of comb just wide enough for one complete row of cells containing eggs is cut with a sharp hot knife. The cells on one side of the comb are then cut down to within a quarter of an inch of the base of the cells. With a match, or a small stick, every other egg is destroyed, or two out of every three eggs. This strip of comb is fastened to the lower edge of a partly built comb which has been cut away to receive it.

---

*This plan, usually called the "Case" plan in this country, was also advocated by Hopkins, of New Zealand, as well as by European writers.

[3]Alley, Henry. 1883. *The Beekeepers' Handy Book;* or *Twenty-two Years' Experience in Queen Rearing.* Wenham, Mass. Henry Alley.

The prepared comb is given to the queenless colony which has been made queenless and broodless for 10 hours. The workers change the cells which contain the eggs, constructing them into queen cells which are utilized for requeening, as in the Miller method.

## Commercial Queen Rearing—The Doolittle System[4]

This method of queen rearing is in most general use, and is practiced with variations by both the beekeeper and the commercial queen breeder. As with the other methods, the colonies which have been selected for furnishing the larvae should be fed for several days prior to transferring or grafting,* unless done during a good honeyflow. Often two or three empty combs are given to the colony and these will be filled with eggs and young larvae by the time they are needed. Some beekeepers prefer to insert a marked comb every day and thus are better able to determine the age of the larvae. Others have devised means by which the queen is confined each day to an empty comb by means of queen excluder material. It is generally agreed that larvae less than 3 days old, preferably 12 to 36 hours old, are of the best age for grafting into artificial cells.

### Artificial Cell Cups

Artificial cell cups made from beeswax, or depressions in wood bases coated with beeswax, are placed on bars which are fitted into an empty frame. The original Doolittle cell is a wax cup made by dipping a stick, with a rounded end and of the exact shape and dimension of the inside of the queen cell, in liquid beeswax. The cell-molding stick is made of hard wood and measures from 1/2 to 3/8 inch in diameter, having a taper of 1/8 inch toward the rounded end. When one layer of the dipped wax is cooled, the process is repeated four or five times, the stick being dipped a shorter distance each time to produce a cup having a thin wall and a thick base. To facilitate removing the finished cell from the stick, it is wet before dipping. Compressed wax cell cups now are manufactured which have a sharp edge and thin side wall, while others have a flanged projection on the base so they may be readily fastened on the cell bars.

Cups with wood bases are used extensively. The finished cell can be transferred from one bar to another and handled with less danger of injuring the immature queens. They usually are cylindrical pieces of wood having a concave depression in one end which is coated with beeswax, or into which a regular wax cell cup may be inserted. They are sometimes made with a flange at the upper end for supporting them when inserted into holes in the cell bars. Generally, they are equipped with a sharp tack in the base which can be pressed into the cell bar, and yet

[4]Doolittle, G. M. 1889. *Scientific Queen-Rearing.* Hamilton, Ill. American Bee Journal.

*The transferring of the tiny larvae from the cells of the comb to artificial queen cells is commonly called grafting.

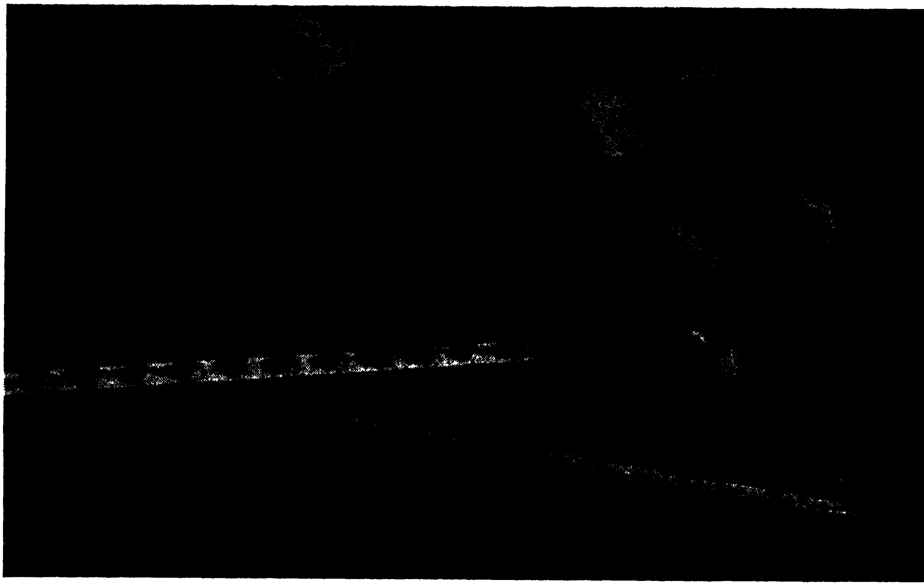


FIGURE 265. The tiny larvae are transferred from the cells of the comb to the wax cell cups with a metal grafting spoon. (*Photo by Milledge Murphey, Jr.*)

allows the finished cell to be easily and gently removed. After cleaning and coating the depressions with beeswax, they may be used again.

### TRANSFERRING OR GRAFTING

The cell cups should be supplied with a small amount of royal jelly, preferably thinned with a little warm water, before transferring the larvae to them. The supply of royal jelly may be obtained from partly built queen cells of a queenless colony, or from queen cells in process of being finished in the cell-building colony. The grafting must be done in a warm place and the grafted cells kept warm until they are inserted into the cell-starting colonies.

Grafting houses are a part of most queen-rearing outfits and should be at least 4 by 8 feet in size, with sun exposure to allow the operator the best light for transferring the tiny larvae to the prepared cells on the cell bars. "Shirt-sleeve" temperatures are about right (75° to 90° F.) and the house should be properly insulated and shaded to avoid excessive heat. Moderate humidity should be maintained.

The frame containing the young larvae now is removed from the chosen hive and carried to the grafting house where the bars of cells containing the royal jelly have already been prepared although some breeders prefer to insert the royal jelly into the cells on the cell bar as they graft. The comb containing the larvae is placed horizontally on the table and raised to a slight angle in front of the operator. The larvae then are transferred to the prepared cells by means of a grafting spoon or

needle—a pointed stick, match, quill, or metal instrument flattened at the end so that it will pick up the tiny larvae more readily (Fig. 265). The grafting spoon is carefully inserted in the cell under the larva, which is "floated" gently onto the spoon and as gently floated off onto the royal jelly at the base of the prepared cell.

Beekeepers are individualists, and queen breeders are no exception. While nearly all commercial breeders use the Doolittle system, many have variations of their own. In some cases, queen cell cups, after being attached to the cell bars, are given to the bees to be accepted and "shaped" before the royal jelly and larvae are placed in them. Others transfer larvae to the cell cups, introduce them to the cell-starting colony, later take them out, remove those larvae, and graft new larvae into the same cells. It is contended that this "double grafting" assures a larger percentage of acceptance and finished cells. "Dry grafting," without royal jelly, sometimes is done, the royal jelly being supplied in ample quantities by the copiously fed young bees in the starter colony. Generally, however, the "wet graft" with royal jelly is preferred because the larvae are not so apt to dry before acceptance in the cell-starting colony.

### Starting the Queen Cells

As pointed out by Snelgrove (see Ref. 1 in this chapter), cells may be started in three ways: (1) By a colony of bees, queenright and with brood, pollen, and stores, (2) by an unconfined queenless colony with or without brood but supplied with stores and pollen, (3) by a broodless and queenless colony in confinement. All methods require strong colonies with ample stores of pollen and honey, plenty of bees, especially nurse bees, and warm weather to secure best results.

By the first method, popularized by Dr. C. C. Miller, when a colony has become very strong, two or more bodies containing drawn combs are placed above the brood chamber. Into the upper one of these is transferred from the brood nest of the colony one or more frames of eggs, or young brood, with the adhering bees. An upper entrance is provided for them to the rear of the colony. These bees are so far removed from the main part of the colony that they are almost a colony to themselves, though they get the benefit of the heat of the colony below. They consider themselves queenless and immediately start to raise queen cells. The mature cells may be used for requeening, one cell being left in the upper colony, if desired, or grafted cells may be introduced into the upper colony. This method often is used in connection with the Demaree method of swarm control, the upper colony being re-united in due course of time. *This is not a part of the Doolittle system, however.*

With the second method, the queen is removed from an exceptionally strong colony which has been selected to start the queen cells. All of the unsealed brood is removed, the bees being brushed off into the colony to restore its original population. Unless there is a good honeyflow the

colony should be fed. About 12 hours later, the colony will be in a mood to build queen cells. The nurse bees, being without brood to feed, will be abundantly supplied with food for the larvae in the queen cells which are to be introduced.*

Most commercial queen breeders use a third method, or what is known as the "swarm box," for starting cells. The swarm box usually is about half the size of a hive body, screened across the bottom and covered at the top to confine the bees. One or more combs of pollen and honey, but no brood, are placed in the swarm box and several pounds of bees are shaken into it. This preferably should be done when the older bees are in the field and out of the hive, because they do not accept queen cells as readily as the younger house bees. Confining a large number of bees without a queen causes them to accept and construct as large a number of queen cells as they would under the swarm impulse. The swarm box should be fed copiously.

After the swarm box has been queenless for a few hours, a frame having one or more bars of cell cups containing larvae is placed in the center. Preferably, 20 or 40 grafted cells are given at one time, although under favorable conditions many more may be accepted. The freshly grafted cells are left for 24 hours and then removed to the cell-building colony. The swarm box can start several batches of queen cells before it is necessary to restock or break it up, ordinarily about 10 days later.

### Finishing the Cells

The cell-building colony should be a powerful one, preferably occupying two hive bodies. The queen is confined to the lower hive body by a queen excluder and most of the sealed brood is placed below with her. As the brood emerges, room is provided for the queen to lay, thus minimizing the possibility of swarming. The unsealed brood is raised above the excluder, resulting in most of the young nurse bees being in the upper story. The colony should be fed, at least until the honeyflow, and combs of pollen should be added if there is a scarcity of pollen. Those colonies which best accept, nourish, and finish the cells should be maintained as cell builders.

There is a preciseness in the maintenance of the cell builders which taxes the ingenuity of the best queen breeders. If the flow is short, the builders must be fed and emerging brood may need to be added. If the flow is heavy, the cell builders may become crowded and may get the desire to swarm. Brood, bees, and even honey may need to be removed. Cell-building colonies should always be kept at peak strength, but not to the point where swarming is encouraged.

---

*There is considerable misunderstanding, even among queen breeders, as to the difference between the cell-starting colony and the "starter box" or "swarm box," the two terms being used interchangeably. In the former case, bees are used on the old stand; in the latter, a queenless nucleus is confined in a screened box.

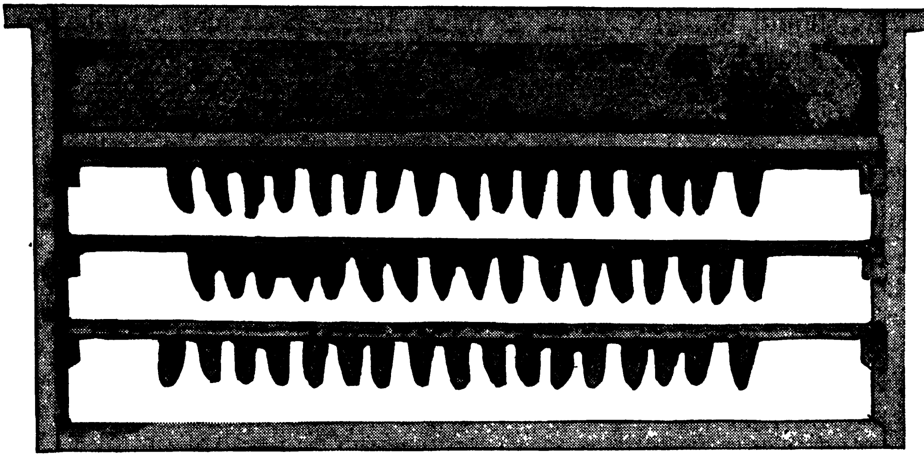


FIGURE 266. Frame containing three cell bars of finished queen cells removed from the center of the cell-finishing colony. (*Photo courtesy John S. Shackelford*)

A frame for holding three cell bars is placed in the upper body between two frames of young brood (Fig. 266). In practice, one bar containing about 16 queen cells is inserted every 3 or 4 days and removed 9 or 10 days later in the same order, new cells being introduced as the bar is removed. Most queens emerge from their cells 10 or 11 days from the time the grafting is done, depending on the age of the larvae used. In commercial queen rearing, it is highly desirable to use larvae as nearly the same age as possible, so that the sealed queen cells in the cell-building colonies will be maturing on the same day (Figs. 267, 268), and a complete bar of cells may be removed at one time. The finished queen cells then are ready to be introduced to the queen-mating nuclei. Ordinarily, two cell-building colonies will supply the queens for at least 50 mating nuclei.

The bar of finished cells should be carried immediately to a warm place. The cells are cut or removed from the cell bar and introduced into prepared nuclei within the shortest possible time. They remain here until the queens have emerged, taken their mating flights, and started to lay, when they are ready to be caged for shipping to customers for use in requeening. Naturally, all small, misshapen, or damaged cells should be destroyed. Cell blocks are preferably used containing holes for safely holding the ripe cells right side up until they are introduced into the mating nuclei.

### QUEEN-MATING NUCLEI

While it is possible to give the mature queen cells to colonies which have been made queenless, this is not done in practice unless the beekeeper is interested in requeening those colonies. Such cells are introduced to smaller, prepared colonies called nuclei. Queen-mating nuclei

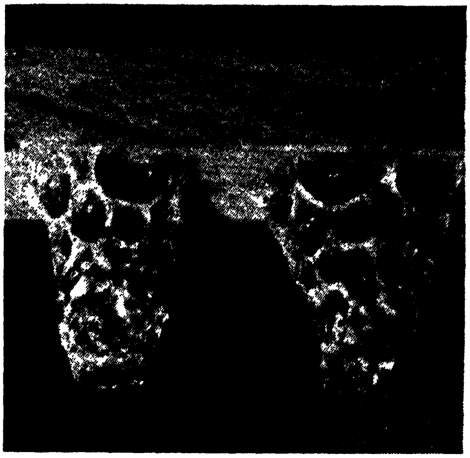


FIGURE 267. Nearly finished queen cells on a cell bar. (*Photo by Milledge Murphey, Jr.*)

FIGURE 268. Finished queen cells ready for the nuclei. (*Photo by Milledge Murphey, Jr.*)

may be made in many ways, but in general there are two types: the small-frame nuclei, and the large-frame type which contains standard-size frames either in the shallow or the full brood depth.

The small-frame nuclei, commonly called baby nuclei, are quite popular with many commercial queen breeders (Fig. 269). The standard baby nucleus consists of two separate compartments each containing two frames, 5½ by 8 inches, and a division-board feeder of similar size, each compartment having an entrance at opposite ends of the box. Three frames of this size are equivalent to a Langstroth brood frame. Usually no brood is used in stocking the baby nucleus. The two frames in each compartment contain comb which has previously been constructed or fitted into the frames. Bees are shaken into screened cages or into screened hive bodies in the outyards and brought to the place where the nuclei are to be stocked. By using bees from a distance, the possibility of the older bees returning to their original hives is circumvented and the danger of robbing is minimized. The bees are fed well, sprayed with water or sugar sirup, and about one-fourth of a pound of bees is shaken into each compartment of the nucleus box. A ripe queen cell then is added, the division-board feeder filled with sirup, and the nucleus is ready to bring its queen to maturity. The queen cell may be given to the nucleus when it is formed, or a few hours later.

Inexperienced queen breeders cannot be too careful in handling the queen cells from the time of their removal from the cell-building colony until introduced into the nuclei. Indiscriminate rough handling, jarring, chilling, or overheating no doubt result many times in inferior queens which otherwise might have proved good mothers of colonies.

Shallow-frame nuclei may be made by dividing a shallow super vertically into two or three parts with a solid partition between, and a sep-

FIGURE 269. A queen-mating yard in the South consisting of many "baby" nuclei, five on each platform for ease in handling. (*Photo courtesy Bessonet Bee Co.*)

arate entrance for each on opposite sides of the hive to prevent confusion when the young queens go on their mating flights. They usually are stocked with one frame of brood, one empty comb, one comb of honey, and a sufficient amount of young worker bees. The queen cell may be introduced when the nucleus is made.

The large nucleus containing full-depth frames is made by dividing the hive body vertically, usually into three compartments (Fig. 270). It is stocked in a manner similar to the shallow-super nucleus but more bees are required. The large nucleus is desirable particularly under unfavorable weather conditions, because it is started with brood in addition to bees and stores.

With either the small or large nucleus, there is a decided advantage in two or three compartments in one unit. They may be worked, fed, and examined more readily, and satisfactory warmth for the brood and the queen is maintained by their close proximity.

Users of the baby nucleus are loud in their defense as being less expensive to maintain and operate, easier to handle, and with no difference in the quality of the queens produced.

On the other hand, the large nuclei advocates are equally as convinced that better queens are produced inasmuch as conditions within the

FIGURE 270. This queen-mating yard contains the larger nuclei which contain standard-size frames, preferred by many.

nucleus are more nearly like those in the normal colony. The nucleus strength is maintained more easily because the emerging bees act as a bolstering aid. Under unfavorable conditions, the bees are apt to abscond from the small nucleus, making it necessary to restock. However, more bees may be added to the baby nucleus from time to time if necessary.

At the end of the queen-rearing season, the large nuclei may be united into colonies for the production of honey by the removal of the hive partitions. Thus, their extra cost of operation is partly offset. Farrar[5] raises the question whether, inasmuch as Nosema disease seems more prevalent in old bees, the large nuclei may not be better because they provide more young bees through emerging brood.

In any case, it is desirable to allow the newly mated queen to remain in the nucleus long enough to observe her laying activities, which also will help in perpetuating the nucleus through the emerging brood. If queen cells are available, another can be introduced into the mating nucleus the day after removing the mated queen. Thus, a mating nucleus may serve for the maturing of several queens in a short time.

[5]Farrar, C. L. 1948. Nosema losses in package bees. *Gleanings in Bee Culture* 76(2):72–75, 119.

### Caging the Queen

When mature sealed cells have been given to the nuclei, the queens may emerge within 24 to 48 hours. It is possible that the queen may take her wedding flight and start laying a week later. Queen breeders generally allow at least 10 days from the time the cells are introduced until the queen may be expected to be laying regularly, and consider the production of two queens each month from a nucleus as being satisfactory. The queen is left in the mating nucleus long enough to determine that she is laying regularly in worker cells and that she is well formed, well marked, physically sound, and otherwise fit to head a productive colony. This is the untested queen as purchased today. The tested queen is left in the nucleus until her worker progeny emerge and it is determined that they are uniform in color and markings.

Much care should be taken in picking the queen from the comb and inserting her into the introducing or mailing cage, as the slightest injury may impair her future value. About 10 young worker bees also are introduced into the cage to accompany and to care for her. The Benton mailing and introducing cage, or a variation of it, is now standard and is usually of the three-hole type, although six-hole cages are commonly used for mailing queens long distances (Fig. 271). One hole in the smaller cage and two holes in the larger one are filled with sugar candy for food.

### Queen-Cage Candy

Most queen-cage candy is made by the Scholz formula, devised years ago in Germany. One pint of honey or invert sugar and 4 pounds of pure powdered sugar is about the right proportion. It is important that the powdered sugar contains no starch. This type of sugar usually is referred to as confectioners' sugar. The candy is prepared by gradually warming the honey, or invert sugar, to about 150° F. and then adding the powdered sugar while stirring. When as much has been added as can be stirred readily, remove the candy from the container and place on a kneading board covered with powdered sugar. Knead thoroughly, adding more sugar until the mass has the consistency of fondant, or putty that will spread well. If the candy has a tendency to "run," more sugar should be kneaded into it. If not used immediately, the candy should be stored in a closed vessel to prevent it from drying.

If honey is used, it should be of highest quality taken from a source where there is no disease. Postal regulations require that each mailing cage carry a statement, previously notarized, that all honey used in candy has been diluted and boiled in a covered vessel.

### Feeding in Queen Rearing

Because the weather is uncertain at the season of the year when queen rearing is at its height and queen rearing must go on uninterrupted once

it has started, feeding becomes almost a necessity at many intervals during queen-rearing operations.

Ordinarily, the starter box and the cell-building colony are fed sugar sirup, 2 parts sugar to 1 part water or a little thinner, and the sirup is given without opening the hive and disturbing the queen-rearing activities. Usually a 1- or 2-quart jar is filled with sirup and inverted over the colony through a hole in the cover of the hive, although some use a similar entrance feeder.

The standard-frame nucleus usually is given a frame of honey when it is formed in the hope that sufficient nectar will be gathered later to keep the nucleus well supplied with stores. Mating nuclei, however, usually are provided with a Doolittle division-board feeder, made the shape and size of a nucleus frame and waxed inside to prevent leakage of the sirup. Screens or floats are provided inside the feeder so that the bees may take the sirup without danger of drowning. Such feeders may be filled readily by carefully opening the nucleus and pouring the liquid from a sprinkling can having a spout bent especially for the purpose.

## The Storage of Combs

Intensive commercial queen rearing reaches its height in the spring and early summer months. After queen rearing has slackened, there is a problem in conserving the combs of the abandoned nuclei. Inasmuch as the wax moths are ever present, it is imperative that the deserted combs of the nuclei be assembled into supers and placed over strong colonies for safekeeping, unless the nuclei themselves are strong enough to be united into full-fledged colonies. Or the combs may be stored in a tight room and treated periodically for protection against the damages of the larvae of the wax moths. For additional information concerning the control of wax moths, see Chapter XXIII, "Diseases and Enemies of the Honey Bee."

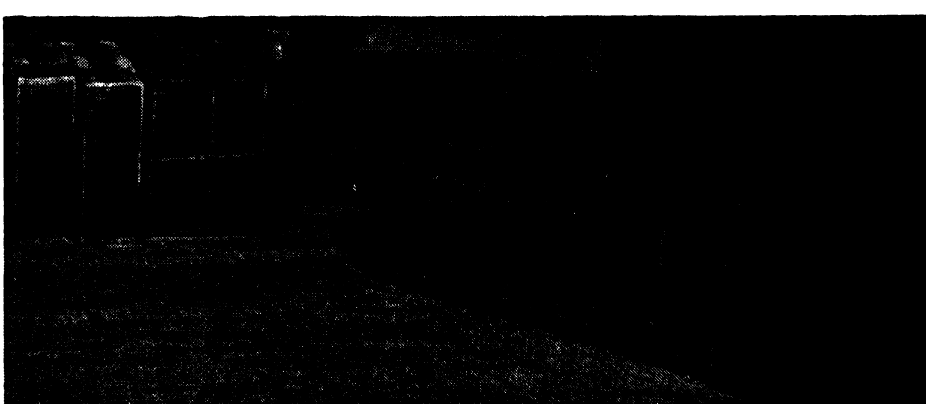


Figure 271. Queens in cages with attendants and candy, ready for mailing to the customer. (*Photo by Milledge Murphey, Jr.*)

## Improvement of Stock

Although progress has been made in recent years, beekeeping ranks far behind many branches of agriculture in selection and improvement of stock. Desirable characteristics, such as honey gathering, disease resistance, gentleness, and color of cappings, have been recognized for many years among varieties of honey bees. However, commercial bee breeders have been unable to combine these characteristics nor have they been able to choose one or more desirable characteristics and maintain them over a period of years. In general, the industry has followed Dr. Miller's advice: "Breed from the best." Because of mismatings of queens with undesirable drone stock, there has been a rapid deterioration of foundation stock which had been selected because of its good qualities. Isolated stations where natural matings may be accomplished with little or no chance of mismatings are, unfortunately, not generally available in this country.

In recent years, considerable progress has been made in controlled mating of queens with the use of instruments. This technique now is developed to the point where it may be put to work in the breeding of better bees. With instrumental insemination and a genetical approach to breeding, much progress may be expected in the development of better bees in the near future. Genetical traits that may be inherited, such as honey gathering, disease resistance, and nonswarming, may be strengthened and passed on from one generation to another, and it will be possible to assemble a number of desirable characteristics in one bee. It is likely that future bee breeding will consider other factors, such as compact brood nests with winter stores placed properly, winter brood rearing, larger bees, regional differences, and bees adapted specially for the production of comb honey or for pollination purposes.

## The Production of Package Bees

Package bees are produced primarily in the Southern States and in California, where colonies may be built to sufficient strength early enough to provide bees which can be sent north for replacing winter losses, for increase, and for pollination purposes. In more northerly areas, many honey producers calculate the cost is greater for overwintering colonies than for the purchase of new packages in spring, and thousands of colonies are killed off in early fall. The production of package bees has increased until approximately a half million packages are supplied each year.

To the inexperienced, the preparation and shipment of package bees seems a simple procedure, but it requires ability equal to that of any other branch of beekeeping. Inasmuch as most packages are in demand in early spring, from March 15 to May 15, the package shipper must have his colonies built up early so that bees may be taken from them at the

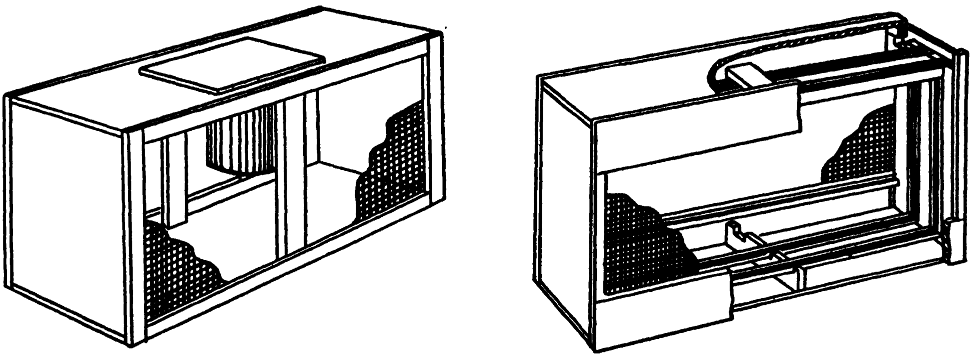


FIGURE 272. Diagram showing two types of package-bee cages. The cage at left is used for the common combless package; the one at right is made to contain three combs and the bees. (*After Whitcomb*)

required time. By midsummer, the colonies will have reached a low ebb in strength, and must be rebuilt for the following spring. Colonies usually are requeened annually to enable them to build to strength rapidly by "package time." The early spring must be propitious and apiaries must be placed where there is ample early flora. They must be accessible in any kind of weather for periodical examinations and for shaking the packages.

### TYPES OF PACKAGES

Whitcomb[6] describes three types of packages or cages: the combless package, the nucleus, and the comb package (Fig. 272). The *combless package* is a shipping container for one or more pounds of bees, without combs, and with a food container filled with sugar sirup. It may be shipped with or without a queen as the customer wishes. The *nucleus* consists of one or more frames of brood and honey with adhering bees. The *comb package* is similar to the nucleus except that it contains one or more additional pounds of bees. The combless package is used most generally, but the use of the nucleus and the comb package is increasing because they contain a more balanced population of bees that build to colony strength more readily. However, they are more costly to buy and to ship, and are not permitted entrance into many states owing to the possibility of disease being present in the combs.

### *The Standard Combless Package*

The standard combless package is 5½ by 9 by 16 inches with the two sides screened with 10- or 12-mesh black screen wire. A number three can, inverted and suspended from the top of the cage, contains sugar sirup which is fed to the bees through two holes, 1/32 inch in diameter,

[6]Whitcomb, Warren Jr. Recommendations for shipping cages for bees. *U.S.D.A. Bull.* E-287.

in the lid. To aid the bees in clustering, wood or wire strips are used in various ways. The queen usually is included in the package in a mailing cage suspended near the center of the top of the cage. The queen sometimes is sent loose with the bees.

In stocking the packages for shipment, the empty cages are taken to the outyard along with the caged queens and the filled feeder cans. The package is placed on a scale and bees are shaken into it through a funnel inserted into the feeder-can hole until the desired weight of bees is obtained (Fig. 273). The 2- and 3-pound packages are the most common sizes, containing about 8 and 12 thousand bees, respectively.

Some producers take the bees from the upper body of a colony, a queen excluder between the two bodies eliminating the necessity of finding the queen and preventing drones from being included. The bees from the lower body may be smoked or drummed upward. Others find the queen, setting the comb on which she is found to one side, and then shaking the bees from the other combs into a funnel containing a queen excluder to eliminate the drones. Some use a "shake box" about the size

FIGURE 273. The bees are shaken from the comb into a funnel, and fall into the screened cage.

of a hive body with an excluder nailed to its bottom, placed over another body closed at the bottom into which the bees run. The packages then are filled with the bees from the lower hive body.

The careful package shipper will have made every effort to have only worker combs in his colonies, thus insuring a high percentage of worker bees. Some rely on this and omit the excluder in shaking. Most shaking is done at the time of day when the field bees are outside the hive, thus assuring a goodly proportion of younger bees. The younger bees should be included in package shipments which are to be used for increase, or for replacing winter losses. If used for pollination purposes, the package should have a well-balanced population (field bees as well as young bees). Care should be taken in shaking bees from a colony not to "overshake" it, thus jeopardizing the future of the colony. With ideal conditions, bees may be shaken from a colony every 10 to 12 days.

Allowances for shrinkage in weight during shipment should be made so the purchaser will receive full weight. The amount of the allowance depends on the nature of the honeyflow at the time the package is shaken. A 2-pound package will shrink from 1 to 7 ounces in shipment. Not less than 20 per cent should be allowed for shrinkage, and most shippers allow 25 per cent to offset amply the loss of weight in shipment. When the proper weight of worker bees is in the package, the queen in the introducing cage and the can of sirup are put in place and the package closed. Sprinkling the prepared package with thin sirup or water is desirable, particularly in warm weather.

### *The Nucleus and Comb Packages*

The cages for the nucleus and comb packages are similar for the two types, the standard size being 5½ by 12 by 19¾ inches. They are usually constructed to contain two combs of brood and honey, and are screened on the sides like the combless package. The selected combs of brood and adhering bees are simply transferred from the colony to the shipping cage and, in the case of the comb package, 1 or 2 pounds of bees are added. When the queen is not with the combs of brood, the cage containing her is placed screen downward and across the tops of the two frames. Usually, the card over the candy is removed so the queen may be released by the bees in transit. A popular nucleus shipping package is a regular hive body divided into two compartments vertically by a solid board. A two- or three-frame nucleus may be placed in each compartment, the bottom closed tightly, and the top screened for shipment.

## Shipping Package Bees

When several packages are sent to the same customer, it is recommended that they be crated in groups of three with at least 4 inches between each package to provide ventilation. The crating strips should extend at least 2 inches beyond the packages to facilitate handling, and

to keep them that distance from the sides of the express car or truck. When only two packages are crated together, strips of the same length as for three packages should be used, thus providing a uniform crate which can be stacked to good advantage. In any case, the packages should be allowed ample ventilation and not be stacked closely together, especially in hot weather when suffocation might occur. Express agents generally are well informed as to the requirements for successful shipment and losses in transit are relatively small unless conditions are unusual.

Package bees are usually shipped by express, although parcel post shipments are permitted with the combless package. Many of the larger buyers load their packages on trucks at the southern breeding yards and transport them overland to their home destination.

As air transport becomes more available, and as its cost is reduced, many packages doubtless will be shipped this way. Air transport should offer great possibilities for the shipment of both queens and package bees, especially where long distances are involved because the time in transit is greatly reduced and temperatures in the air can be easily regulated to those which are best suited for keeping the bees quiet and comfortable.

FIGURE 273a. Calvin Bessonet, an Eastern Air Lines steward, and William Bessonet (left to right) load package bees for air shipment—a method of shipment that is increasing in popularity. (*Photo courtesy E. C. Bessonet*)

# XXII. *Injury to Bees by Poisoning*

BY J. E. ECKERT*

THE honey bee is susceptible to most of the insecticides used as stomach or contact poisons, or as fumigants in controlling injurious insects. The honey bee also is injured in its adult and brood stages by certain plants that produce toxic substances. Fortunately, poisonous plants are limited to a small number of species occurring in relatively few areas in the United States, and are not equally dangerous in successive years. Chemical injury, on the other hand, is widespread and may occur in any area where quantities of insecticides are applied.

The pollination service of the honey bee ranks in importance with proper planting, cultivation, and harvesting of at least fifty of our agricultural crops. Consequently, the loss of bees by chemical or plant poisoning may mean a reduction in the crops which are benefited by bees. In addition the constant use of insecticides kills many insect pollinators other than the honey bee, thus increasing the need for the honey bee, the chief insect which can be produced for pollination purposes.

To the beekeeper the killing of bees by chemical or plant poisons means a monetary loss that varies with the severity of the damage. Many thousands of colonies are destroyed annually by chemicals in Washington, Utah, California, Arkansas, Arizona, Texas, and Louisiana, and considerable damage is done elsewhere. In addition, the numerical strength of many colonies is reduced so that honey production and pollination services are greatly lowered. Often beekeepers must seek new locations because of the hazards of poisoning, frequently overcrowding the floral sources in other regions and reducing the honey secured by resident beekeepers. Thus bee poisoning in one area affects beekeepers in another.

## No Danger of Producing Poisoned Honey

With so many chemicals injurious to bees being applied to cultivated crops, one might suppose that honey would contain some of the poisons. However, this is not the case because bees affected by poisons do not behave in a normal manner. Instead of returning to their hives, they apparently attempt to throw off the effects of the poisons and either become lost or die in the field. In cases of the quick-acting poisons, such as sabadilla or arsenicals and those that affect the bees through fumigant action,

*John E. Eckert, Ph.D. Professor of Entomology and Apiculturist, University of California.

bees can be found hanging on plants and on the ground beneath the plants treated. In the case of DDT, the bees run and fly in a frenzied manner when they feel its chemical effects. As with many other poisons, the population of the hive may be reduced without many dead bees accumulating before the entrances. This is evidence that the affected bees die in the field and do not return to their hives.

Should the bees return to the hive with a load of poisoned nectar, there is a double provision that none of it will get into the stored honey. The hive bees rehandle every drop of nectar, and so are exposed to the poison longer than the field bees. Hive bees have the tendency to leave the hive when they feel the effects of poison, and in this way would carry from the hive any poisoned nectar they might have taken into their stomachs. Further, chemical analyses of honeys, extracted from the brood combs of colonies affected by arsenical poisoning, have failed to reveal any trace of arsenic. *Beekeeping and agriculture are indeed fortunate that poisons are not introduced into honey.*

## Poisoning by Insecticides

In collecting nectar and pollen from flowers, honey bees may come in contact with poisons deposited upon plants in bloom. Nectar gatherers may be killed while filling their honey stomachs, a process that requires several minutes even under favorable conditions, or they may die on the way back to their hives. Pollen collectors, however, may carry the poisoned pollen to the hives in their pollen baskets where it is stored in the cells for feeding brood. The effects of the poison on the brood and the bees continue as long as the poisoned pollen remains in the combs.

The effects of chemical poisoning on an apiary are generally observable on the day the bees have access to a toxic material, and may result in the loss of the field force and a gradual loss of the brood and hive bees within a week or 10 days. For this reason, colonies which are not visited oftener than once in 2 weeks or once in a month are sometimes totally destroyed and their combs partially riddled by the wax moth before the owner realizes that anything is wrong. In many instances, beekeepers have visited their apiaries with the intention of putting on or of taking off supers, only to find their colonies destroyed. In such instances, it is extremely difficult to secure complete evidence as to the source of the poison or the cause of the loss.

### Insecticides Toxic to Bees

Although most chemicals used as insecticides are harmful to the honey bees, some are more toxic than others. *Calcium arsenate, lead arsenate,* and *Paris green* are particularly injurious, even in minute quantities. *Cryolite,* sometimes used as a substitute for calcium and lead arsenate, under field conditions is less toxic than the arsenicals. In the citrus

regions of California, however, cryolite has been the cause of heavy losses of bees. In the apple-growing regions of British Columbia, beekeepers have been able to maintain their colonies when cryolite, instead of lead arsenate, was used against the codling moth. *Xanthone or Genicide,* another chemical used against this moth, apparently is nontoxic to bees. *Pyrethrum, derris,* and *rotenone* dusts are definitely injurious, but less so than arsenicals because their toxicity is rapidly lost upon exposure to the air. *Nicotine compounds,* such as *nicotine sulphate* and *Nico-dust,* are toxic but serve as bee repellents. When applied under certain climatic conditions, however, Nico-dust has killed the field force of an entire apiary. *Sulfur* appears to be nontoxic and acts as a repellent in lime-sulfur sprays. *Tartar emetic* is a mild poison but might be highly destructive if improperly used.

Within the past few years, many new chemicals have been introduced as insecticides, and their relation to beekeeping will not be known until they are used more generally. Laboratory tests with caged bees indicate that many of the compounds are highly toxic to bees in very minute quantities. If the chemicals are applied to plants in a manner that will permit bees to acquire a lethal dose, as indicated by laboratory tests, then a reduction in colony strength can be expected.

A number of *hydrocarbons* and *phosphates* have been introduced recently which are toxic to a wide variety of insects. Some of these are replacing the older insecticides. Many are toxic to bees and to other insects as contact insecticides and stomach poisons, and a few have fumigant action as well. Because of their multiple toxicity, the newer chemicals frequently give better insect control when used in comparatively smaller amounts than the arsenicals.

The hydrocarbons, which include DDT, DDD, hexachlorocyclohexane, and chlordane, are insoluble in water and are effective as contact and stomach poisons.

*DDT* (dichloro-diphenyl-trichloroethane) acts both as a stomach poison and as a contact poison to the bees. Taken internally, it is somewhat less toxic than calcium arsenate, the median lethal dose in sugar sirup being approximately 4.6 micrograms* per bee. Bees that are dusted with material containing as little as 1 per cent of DDT may die within a few hours; those that walk over a surface sprayed with a 2-per cent solution will die within 12 hours if they remain in contact with the surface for 20 to 30 minutes. The material is rather stable, persisting as a poison for several weeks, or even months, after its application.

*DDD* (dichloro-diphenyl-dichloroethane), while less toxic to honey bees than DDT, is more effective than arsenicals against certain insects. The median lethal dose is approximately 16 micrograms per bee. It takes larger quantities of DDD dusts to kill bees on contact and consequently

---

*A microgram is one-millionth of a gram. There are 28.4 grams in an ounce.

DDD can be considered as a safer insecticide, as far as bees are concerned, than the arsenicals or the other hydrocarbons. *Hexachlorocyclohexane,* better known as 666 or as benzene hexachloride, is slightly more toxic than DDT and affects the bees in much the same manner.

*Chlordane* (first identified in this country as 1068 and now sold in various compounds, including Octa-Klor, Dowklor, and Velsicol 1068) has a higher toxicity to bees than the other hydrocarbons named. The median lethal dose is approximately 1 microgram per bee when the material is dispersed in sugar sirup. A small quantity of the dust will kill bees within 7 to 8 hours. When bees come in contact with a surface covered with a spray containing 5 per cent chlordane for only a few minutes, they will die within 3 to 12 hours. Furthermore, bees which remain in contact with the fumes of this chemical, although not in direct contact with a treated surface, will die within a few hours. In one experiment, the walls of a comb room, 10 by 12 by 8 feet, were sprayed with a 5-per cent chlordane suspension in water as a means of controlling ants. Bees in cages were killed when placed in this room one year after the walls had been sprayed. Two combs left in the room for 2 weeks and then placed in 3-frame nuclei killed the bees within 48 hours. The residual effect of this chemical has yet to be determined for many circumstances, but it cannot be used with safety where bees or combs come in contact with it or its fumes.

The phosphates which have been introduced as insecticides are more toxic to bees than the hydrocarbons. *HETP* (hexaethyl tetraphosphate) was the first introduced, and was followed by *TEPP* (tetraethyl pyrophosphate) and by *parathion.* All three are toxic to bees on contact or when incorporated in honey or sugar sirup. The median lethal dose for HETP is between 0.24 and 0.34 microgram, and that of TEPP is 0.075 microgram per bee. A dilution of 1 part of TEPP to 1,500,000 parts of sugar sirup killed 43 per cent of caged bees within 24 hours. Parathion, which has the complicated chemical formula of O,O-diethyl O-p-nitrophenyl thiophosphate, has about the same median lethal dose as TEPP. However, parathion produces a greater fumigant action than either of the other phosphates and a longer residual action, and so may be considered as potentially more dangerous to beekeeping. Bees that come into contact with dusts containing only 1 per cent of parathion are killed or incapacitated within a few minutes. Fortunately, water solutions of the phosphates lose their toxicity within 24 to 48 hours. This would indicate that it would be comparatively safe to move colonies into an area in which phosphates had been used if the move is made 48 hours after the sprays have been applied.

Because new chemicals may be incorporated in pest-control programs at any time, it is important for every beekeeper to keep informed of the spraying and dusting needs of each locality in which his colonies are located.

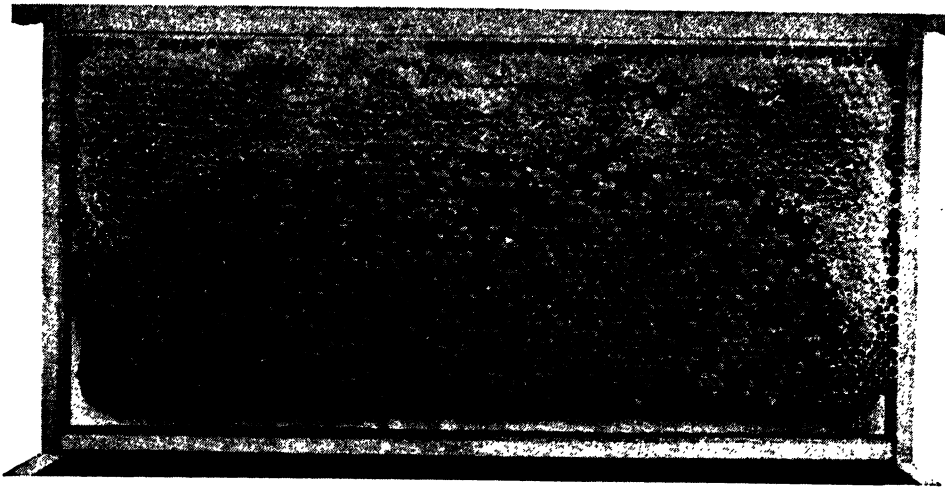


FIGURE 274. The appearance of a comb of brood a few days after the colony was injured by calcium arsenate. All unsealed brood has been removed. (*Photo by J. E. Eckert*)

## INJURY CAUSED BY INSECTICIDES

Soluble poisons in nectar, contact poisons, and fumigants generally affect the bees before they can return to their hives, but when in pollen the effect on the bees and brood continues for days and weeks. The greatest death rate of brood and hive bees occurs within the first few days. The poisoned pollen generally causes the death of the nurse bees that elaborate it into food. The nurse bees die in the hive or crawl from the bottom board to the ground (Figs. 274, 275), and the poisoned larvae usually are removed from their cells within a few days. The death of the nurse bees apparently safeguards the queen, for she is generally the last to succumb in a colony fatally injured by chemicals. The killing of the field force reduces the amount of poisoned pollen that is stored. Nevertheless, enough pollen may be gathered by the pollen collectors to destroy the colony.

In an apiary that is severely injured by arsenic the ground may be carpeted with dead and dying bees soon after the poison is secured. The affected bees fly for short distances, crawl up blades of grass or weeds, and hop away from the hive, often collecting in depressions or becoming hidden in the grass. In the chill of early mornings, small groups of stricken bees may be found huddled together. As the day becomes warmer, those still active crawl and hop away, frequently toward the sun. Such bees, when analyzed chemically, have been found to contain from half a part to several parts per million of arsenic trioxide.

A week or 10 days after the first effects of arsenical poisoning are observed often only a few hundred newly emerged bees remain with the queen. Strong colonies thus may be destroyed between periodic visits of the beekeeper. Aside from dead bees on the ground around the hive, lit-

tle evidence of the cause will be seen. Severely injured colonies may cast forth small swarms, containing no more than a couple hundred bees and the queen, apparently in a final effort to escape from the destructive forces operating against them. In less severe injury the colony population may decline slowly. The colony may live for several weeks, or even survive if too much poisoned pollen has not been stored and if fresh pollen becomes available. The presence of poisoned pollen in the combs may be more serious to the welfare of the colony than the reduction of the field force. Pollen taken from the combs of a stricken colony has contained as much as 30 parts per million of arsenic trioxide, and only ½ to 1 part per million is sufficient to kill a worker bee.

Although chemical analyses of dead larvae may indicate sufficient arsenic to have caused their death (Fig. 276), some of the brood may starve or die from neglect if the hive bees are decimated rapidly by the effects of the poison.

Bees affected with cryolite behave in much the same manner as those stricken with arsenic. Numerous "hoppers" appear soon after the poisoned pollen is carried to the hive and many bees may be found on the

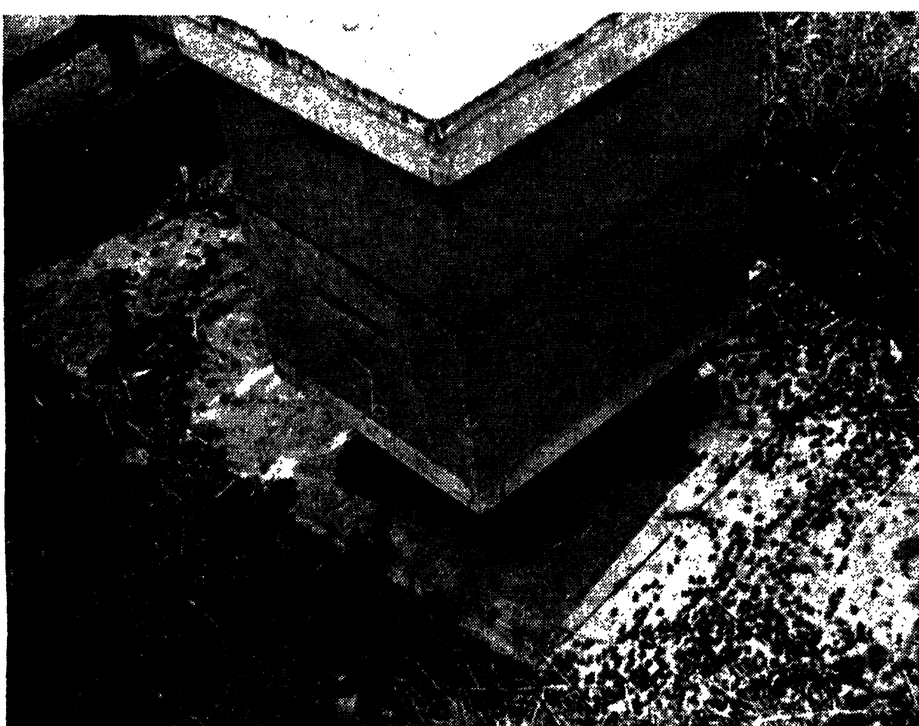


FIGURE 275. Dead bees around a hive the day after calcium arsenate dust was spread by airplane over the surrounding fields. These bees were mostly nurse bees killed by the poisoned pollen carried in by pollen collectors. (*Photo by J. E. Eckert*)

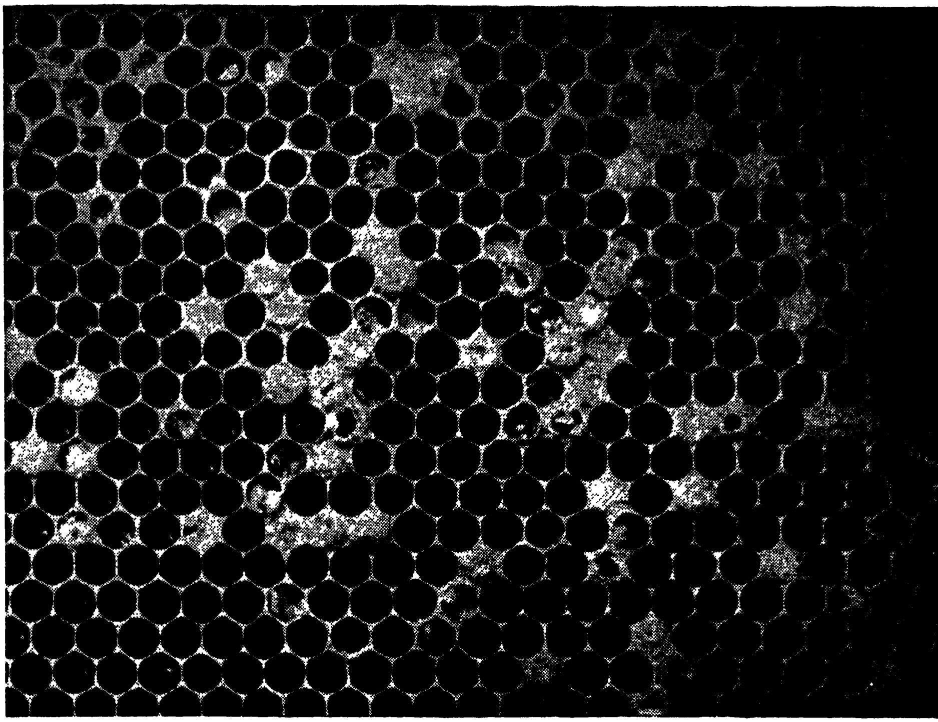


FIGURE 276. Portion of a comb showing brood poisoned by calcium arsenate. Note that most of the younger larvae have already been removed from the cells. (*Photo by J. E. Eckert*)

ground for several feet in front of the hive. If the ground is covered with grass or weeds, dead bees will be found near the hive. In the case of both arsenic and cryolite, the accumulation of dead bees before the entrance will be in proportion to the amount of poisoned pollen carried into the hive.

Bees will work blossoms in fields which have been sprayed or dusted with the hydrocarbons, phosphates, arsenicals, or cryolite because these compounds are not repellent to the field bees. When they come into contact with the dusts or sprays containing DDT, the bees become agitated and fly more rapidly from plant to plant, and finally disappear. Dusted fields may become depopulated within a few hours, indicating that those bees which on previous days had oriented their activities to the fields have either been destroyed or caused to leave by the contact stimulus of the DDT. Other bees will orient themselves to the fields within a day or two and can collect nectar and pollen from newly opened flowers in apparent safety.

If the hydrocarbons are applied to a sufficient acreage in large enough quantities to cause the loss of the field force, the effect will be a noticeable reduction in the numerical strength of those colonies working in the

treated fields. In some cases this has resulted in the loss of the field force and in the reduction of the honey crop. The brood of the bees apparently is not affected. This may be due to the fact that the pollen collectors, as well as the nectar gatherers, become so injured that they are unable to return to their hives, or that insufficient amounts of the chemicals are carried back with the pollen. It also has been discovered that a considerable amount of DDT can be mixed with the pollen of bees without apparent injury to the nurse bees or to the brood.

If chlordane compounds, or those containing parathion, are applied in sufficient concentrations to be injurious to bees through contact, ingestion, or fumigant action, the resultant loss of the field force might reduce the population of their colonies below the point where the colonies would be useful as honey producers or as pollinating factors. In some instances, where chlordane was applied to alfalfa for the control of grasshoppers, no appreciable injury was noted to colonies in the near vicinity. In another instance, the application of chlordane dust to alfalfa caused a 50 to 80 per cent reduction in the field force of many colonies.

### Treatment of Injured Colonies

If only the field force has been affected, as indicated by the presence of healthy brood and a good force of hive bees, the trouble may be temporary. If arsenic has been applied as a dust, the colonies should be removed from the area as soon as possible in order to prevent the bees from carrying back to their hives any additional poisoned pollen. If the loss of bees is the result of the application of hydrocarbons, and no more applications are to be applied in the vicinity to blooming plants which are attractive to bees, the colonies generally need not be moved.

If the brood and nurse bees also are affected, poisoned pollen evidently is present and not only should the apiary be moved to a safe distance, but the combs containing this pollen should be eliminated. If the injured colonies are strong enough, they can be shaken onto combs known to be free of poisoned pollen. Experience has shown that as long as brood combs contain poisoned pollen, whether from insecticides or from a plant source, normal development of the colony will be retarded. In several instances package bees or swarms have died when placed on combs from colonies which previously had been poisoned. Even when colonies may survive, their development is frequently so retarded that they may be of little practical value for several months (Fig. 277).

Combs containing brood as well as pollen can be concentrated in a limited number of hives until the bees emerge, and then treated to remove the pollen. The combs can be soaked in water for 24 to 48 hours, after which the water can be shaken out by hand or thrown out in an extractor, and the combs dried quickly. On drying, the pollen shrinks in the cells and the bees can remove it without injury. Some beekeepers believe that soaking damages the combs too much and prefer to divide the

combs among strong colonies during a honeyflow. This may result, however, in more colonies being weakened.

## Insecticide Control Measures

Practically every cultivated plant has one or more insect enemies which have to be controlled in order to safeguard the labor and investment of the grower. Insects are controlled by cultural practices, by chemical means, and by natural insect enemies. With the concentration of various crops in large acreages, the chemical control of insects has proved to be the quickest and most practical method for most cultivated crops. The application of chemicals that are poisonous to the insect pests generally results in killing off the predators and parasites as well, thus requiring the use of more chemicals in the control of the pests.

Honey bees are essential to a balanced plan of agriculture and should be given consideration in every insect-control program. Some states recognize their importance and prohibit the application of substances toxic to bees during the blooming period of deciduous trees. In other regions, cer-

FIGURE 277. The remains of a strong three-story colony 2 weeks after the first effects of calcium arsenate poisoning were noted. Such colonies seldom survive. (*Photo by J. E. Eckert*)

tain crops have to be protected from injurious pests by chemicals that are highly injurious to bees. If these crops are not benefited by the visitation of honey bees, little or no consideration may be given to the need of using materials or methods which will cause the least injury to insects that are beneficial to other crops. County ordinances have been enacted in some regions to regulate the use of chemical substances for the mutual welfare of all phases of agriculture. Unfortunately, many growers and pest-control operators are not aware of these regulations or do not consider the need for safeguarding honey bees when they apply pest-control measures.

County, state, and federal laws are effective only insofar as they can be impartially enforced; to be workable, they must benefit the majority of interests in any community. Beekeepers and growers alike can benefit themselves by working for the use of improved materials and methods of control which will be less injurious to the pollinators and other beneficial insects, and by influencing the enactment and enforcement of more adequate legislation to control the use of agricultural poisons. The formation of county committees, composed of representatives of all phases of agriculture, to investigate, to recommend, and to supervise the use of poisons for the mutual welfare of all, has resulted in several instances in reducing the hazards from the use of chemicals and in an improvement in the control of injurious insects.

Beekeepers can reduce their losses by becoming familiar with the insect-control programs of the regions in which they are located, by registering the location of their colonies with county officials who have authority over the use of insecticides, and by constantly publicizing the value of honey bees to any balanced agricultural program. In the event of poisoning, beekeepers should immediately notify their county and state regulatory authorities and collect all evidence which would indicate the cause.

Sometimes colonies are purchased or leased for pollination purposes and the rental charges often are governed by the magnitude of the hazards from chemical poisoning. When growers pay a rental for colonies for pollination purposes, they appreciate their value and the need for protecting them from the destructive effects of poisons. Poisons should not be applied during the blooming period of a plant if control of insects or diseases can be effected at any other stage. When such applications are necessary the beekeepers, and others who might be adversely affected by the application of poisons, should be notified and given sufficient time to move their colonies, or to influence the substitution of less destructive methods of controlling insect pests.

If poisons are confined to fields being treated and are used only in necessary quantities, with due notice issued before their application, the loss of bees will be kept at a minimum. Poisons that are the least toxic should be used if they give control of the injurious insects. The poison

might be applied in the early morning or late afternoon when the flowers are closed, as with melons, cantaloupes, and other members of the genera *Cucumis* and *Citrullus,* thus preventing the destruction of pollinators.

The introduction of the newer chemicals may result in improved insect control and in a reduction of the losses now produced by the use of arsenicals and other chemicals. Investigators have found that certain hydrocarbons, used alone or in combination with other chemicals, can be used to replace the arsenicals in the treatment of the insects of deciduous fruits, cotton, potatoes, tomatoes, and many other field crops, and need be applied only in comparatively small amounts. McGregor and Vorhies[1] have demonstrated that beekeeping is feasible in the vicinity of cotton fields when DDT was substituted for arsenicals in the control of cotton insects. Beekeeping also has flourished in areas where deciduous fruits, potatoes, and truck crops are grown when hydrocarbons were substituted for the arsenicals.

These results may not seem consistent with the laboratory tests indicating that the newer chemicals are highly toxic to bees. The difference between the disastrous losses caused by arsenicals and the reduced hazards when hydrocarbons are used apparently is due to the comparative amounts of the chemicals needed to effect insect control. For example, in the control of tomato insects in California three applications of chemicals are generally necessary. When calcium arsenate is used, approximately 21 pounds per acre are applied on each of three applications, or a total of 63 pounds. When DDT or DDD is used, the most that is needed to effect better control is 1.5 pounds of toxic materials for each application, or a total of 4.5 pounds. Inasmuch as bees do not visit the tomatoes, it is obvious that the losses are incurred by the poisons that drift over adjacent property.

It is a fallacy, however, to say that the hydrocarbons are not injurious to bees under field conditions without giving the circumstances under which they have not proved to be injurious. If the newer chemicals are applied in larger concentrations than the minimum doses indicated, or if they are applied to field or orchard crops while the bees are working the blossoms for nectar or pollen, serious losses of the field bees may result.

When the hydrocarbons are applied over large areas for mosquito-abatement purposes, beekeepers have found that 0.1 pound per acre caused no noticeable injury to their colonies. It also has been observed that no material loss of bees has resulted and the bloom of the alfalfa has been more profuse when DDT was applied to seed alfalfa in the prebloom or early bloom stages for the control of alfalfa insect pests. In the Imperial Valley of California, the application of 5 per cent DDT to alfalfa for the control of alfalfa butterfly resulted in no economical loss of bees with a prolongation of the nectarflow, according to W. C. Miles, a bee-

[1]McGregor, S. E. and C. T. Vorhies. 1947. Beekeeping near cotton fields dusted with DDT. *Ariz. Agr. Exp. Sta. Bull.* 207.

keeper of San Bernardino and Imperial counties in California. Economic losses of bees have been reported, however, by several beekeepers in California, Utah, and Washington when dusts containing 10 per cent DDT were applied to large acreages of alfalfa in full bloom. Elmer Hastings, of Mesa, Arizona, reported the loss of the field force of colonies located in citrus groves dusted in full bloom with DDT. The colonies regained their strength in 7 days, but the honey crop was reduced about 50 per cent.

The phosphates have not been used extensively enough in the field to give their probable effect on bees. Dead bees have been observed under citrus trees experimentally treated with phosphate sprays or dusts. It is highly probable that the phosphates will be used widely in the control of mites, thrips, aphids, and other insects.

The dinitro compounds, when used for control of mites and red spiders on citrus and deciduous fruits, or when employed as blossom thinners on apples, are potentially dangerous to bees working the sprayed blossoms. Goble and Patton[2] found that *Elgetol,* whose active ingredient is the sodium salt of 3,5-dinitro-o-cresol, was toxic to bees which consumed only 0.0029 ml. of a dilution containing 1 ounce of active ingredient to 100 gallons of water. The median lethal dose of this compound was computed to be 2.39 micrograms per bee at 70° F. and 2.13 at 90°, relatively large amounts when compared to the median lethal doses of the phosphates, but about twice as toxic as DDT. The bees did not visit the trees when the blossoms were wet with spray and, as a rule, the blossoms were less attractive after the spray had dried. Chemical analyses of pollen collected by bees showed only a trace of dinitro, and the chemical could not be found in nectar taken from bees working the sprayed blossoms.

Bees may fly several miles in quest of nectar and pollen, so it is entirely possible for them to secure poisons from plants located two or more miles from their hives. The direction of the prevailing winds and the wind velocity at the time poison dusts are applied have a direct bearing on the potential danger to bees of poisons applied within a radius of 5 miles of the fields treated, because poison dusts may drift 2 or 3 miles from them.

Because the destruction of honey bees influences the crops of farmers within 2 or 3 miles of the apiaries, the beekeeper is not the only one affected. The spraying of orchards while the trees or cover crops are in bloom kills the pollinators that produce the fruit and seed in that area. Dusts applied by airplanes (Fig. 278) or powered blowers to a tomato field may drift over an adjoining alfalfa field, reducing the value of the hay and killing the pollinators that work on the blossoms. The drifting poisons do not help the grower and may result in a loss of as much as 50 per cent or more of the dust used. Lighter applications confined to the fields treated would be more efficient and would cause less injury.

[2]Goble, G. J. and R. L. Patton. 1946. The mode of toxic action of dinitro compounds on the honey bee. *Jour. Econ. Ent.* 39(2):177–180.

FIGURE 278. An example of the inefficient application of calcium arsenate by airplane. When the light dust is applied at such heights, a great majority of the poison never gets down to the plants. The entire bank of dust in the distance drifted from the field in less than 5 minutes and traveled for at least 2 miles, depositing poison on all vegetation over which it passed. (*Photo by J. E. Eckert*)

Dusts of larger particle size are less prone to drift. Machines equipped to apply a fine mist and dust at the same time, or machines equipped to apply liquid sprays, are much more effective in confining the poisons. Canvas drags behind dusting machines also tend to reduce the hazards but are less efficient than sprays. Liquid sprays can be confined to the plants and can be applied under a wide range of climatic conditions by ground machines or from the air. To permit poisons to drift at random is a misuse of the privilege and should be prevented by adequate laws, special licensing, and impartial supervision.

## Use of Repellents

To be effective a bee repellent must be strong enough to prevent the honey bees from collecting poisoned nectar or pollen from sprayed or dusted plants, yet it must not injure any part of the plant or harm the operator applying the poison. Nicotine sulphate, creosote, carbolic acid, lime sulfur, naphthalene, and similar substances, commonly mentioned as bee repellents, have only limited use because the efficiency of each depends upon its volatility. Many poisons are practically indestructible, their effect continuing at least as long as the flowers are attractive to bees. Some flowers remain open 10 to 12 days and repellents are seldom effective for that long.

Bourne,[3] Southwick,[4] Shaw,[5] and other investigators have experimented with several materials containing nicotine sulfate, creosote, tar oil, phenol compounds, naphthalene, and other chemicals in search of a suitable repellent to bees. None of the compounds tried were found very effective although some did decrease the number of visits of bees.

### Recommendations Concerning Chemical Poisoning

The pollination services of honey bees are essential to a well-balanced plan of agriculture. Beekeeping cannot survive where promiscuous applications of poisons which are toxic to bees are permitted. The only hope of maintaining the industry in such places lies in (1) more efficient control to prevent the misuse of poisons, (2) use of poisons that are less toxic to beneficial insects, (3) efficient application with consequent reduction in the total amounts of poisons used, (4) more effective advice to growers concerning spraying and dusting equipment, materials, and treatment, (5) the development of more efficient spray equipment, and (6) the development of suitable repellents.

## Plant Poisoning

Plant poisoning usually is less severe than poisoning by insecticides because it is restricted to areas where poisonous plants occur, but, nevertheless, causes the death of many colonies. Fortunately, the products of these plants, although poisonous to bees, are not injurious to man if they occur in honey. There is one possible exception—according to authenticated reports, the honey from mountain laurel has sometimes caused acute illness soon after being eaten. The plant occurs largely in the mountains of New Jersey, Virginia, and North Carolina. Inasmuch as this honey is not always injurious, weather conditions may be involved. The amount of honey produced is not large and is discarded by beekeepers.

### Plants Poisonous to Bees

Of the innumerable plants visited by honey bees, comparatively few produce nectar or pollen poisonous to bees or to their brood. The effect of the injurious plants varies with environmental conditions, and the severity of the injury is affected by the number and condition of other plants more attractive to bees in the same area. The following are the most important plants poisonous to bees or suspected of so being: California buckeye (*Aesculus californica*), black nightshade (*Solanum nigrum*),

---

[3]Bourne, A. S. 1927. The poisoning of honey bees by orchard sprays. *Mass. Agr. Exp. Sta. Bull.* **234**:74–84.

[4]Southwick, A. M. 1938. Creosote in spray poisoning. *Gleanings in Bee Culture.* **66**: 239–240.

[5]Shaw, F. R. 1941. Bee poisoning: A review of the more important literature. *Jour. Econ. Ent.* **34**(1):16–21.

FIGURE 279. Appearance of newly emerged bees killed by California buckeye poisoning. (*Photo by Geo. H. Vansell*)

death camas (*Zygadenus venenosus*), dodder (genus *Cuscuta*), leatherwood (*Cyrilla racemiflora*), locoweeds (genus *Astragalus*), mountain laurel (*Kalmia latifolia*), western false hellebore (*Veratrum californicum*), and yellow jessamine (*Gelsemium sempervirens*).

### INJURY CAUSED BY POISONOUS PLANTS

The toxic substances in poisonous plants are specific in action and may be confined to the nectar or simply to the pollen. Symptoms of plant poisoning are sometimes difficult to recognize or to be substantiated by chemical or microscopical diagnosis. The presence of symptoms usually is limited to the blooming period of the plant if the nectar is affected and, if the colony survives, the symptoms may disappear with the bloom. However, if the toxic substance is in the pollen, the symptoms may linger as long as the supply of pollen remains in the combs.

When only the adult bees are affected, piles of them may be found dead in front of the hive entrance, and there may not be enough adults to take care of the brood or combs. The field bees may die away from the hive and newly emerged bees may leave the hive and crawl upon the ground, or lie there stupefied or dead. Newly emerged bees may have

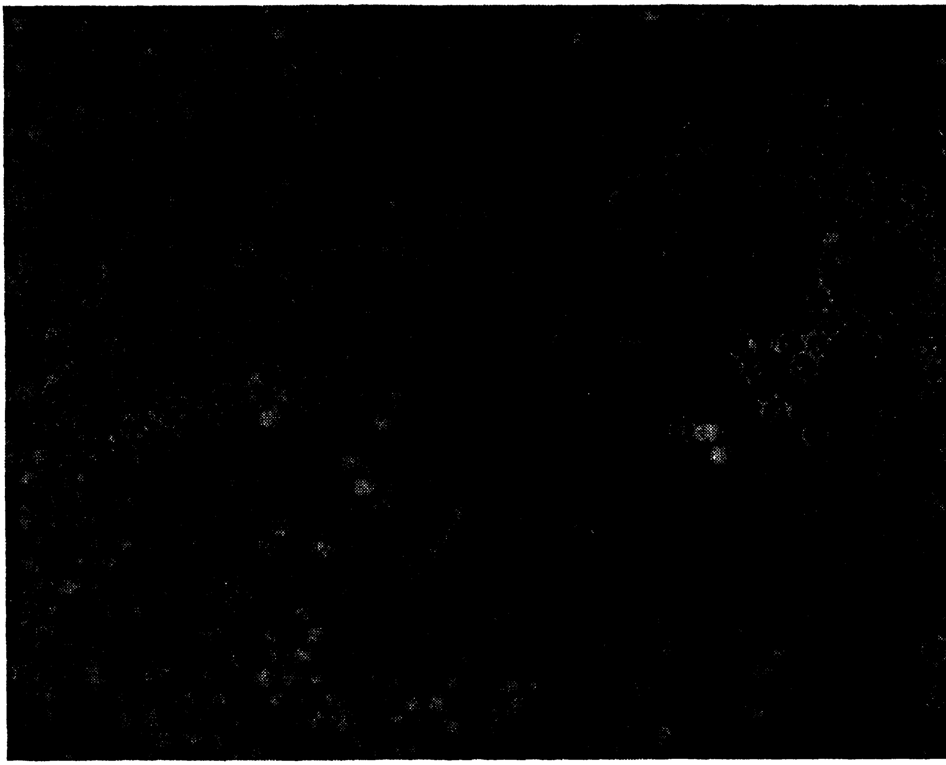


FIGURE 280. Portion of brood comb showing pupae and adults at the stage of emergence killed by locoweed poisoning. The younger pupae were white and were partially removed, while the heads of the bees about to emerge were worn shiny by the efforts of the workers to remove them. (*Photo by J. E. Eckert*)

crumpled wings, or fail to shed the last pupal case from the abdomen (Fig. 279). When poisoned by California buckeye, some of the field bees become black and shiny from loss of hair and may tremble as in an advanced stage of paralysis. For additional information concerning paralysis, see Chapter XXIII, "Diseases and Enemies of the Honey Bee."

Brood affected by plant poisons may die any time between the hatching of the egg and the emergence of the adult. It generally lacks the brown or black colors associated with American and European foulbrood. In buckeye poisoning, larvae die soon after hatching and are removed quickly. In cases of plant poisoning reported from Florida and Georgia, larvae die in all stages, accumulate in the cells, and appear blue. In one instance, attributed to locoweed poisoning, many individuals died in the late pupal stage, and bees about to emerge dried or mummified in their cells (Fig 280).

Queens are affected by buckeye poisoning and much of the injury to the colony seems to stem from their behavior. Affected queens produce eggs that do not hatch or larvae die soon after hatching. The queens also

may become incapable of laying or may lay only drone eggs. They frequently recover their egg-laying ability, partially or completely, after the colonies are removed from the buckeye territory or when other plants furnish a pollen source. Affected colonies often try to supersede their queens, but usually fail and colony mortality may be high. Some hybrid strains are more resistant to certain plant poisoning than purer strains.

### Detection of Plant Poisoning

There is no specific rule for differentiating between plant and insecticide poisoning. Whenever symptoms of poisoning occur, a careful examination should be made of the brood, the amount of pollen present, the colony strength, and the accumulation of dead and deformed bees. In plant poisoning, other than buckeye, investigation may reveal large numbers of dead bees beneath or around the plants, in front of the hives, and all over the ground for some distance away from the hives. The effects usually are more gradual than in chemical poisoning and generally recur in the same area, but not necessarily with equal severity.

### Treatment

Familiarity with the nectar and pollen plants within flight range of each apiary is a definite aid in formulating practices to prevent plant poisoning. Wherever the injury causes colony death or reduces colony strength below a producing level, bees should be kept away from the suspected territory during the blooming period of the plant in question. With the California buckeye, about 15 million acres seem to be involved, and thus an important area of land is rendered unavailable for beekeeping for about 6 weeks in early summer. In seasons when other plants within this area provide a substantial source of pollen and nectar, the damage is less severe.

When toxic substances occur in the pollen, the removal of pollen-clogged combs from affected colonies is definitely helpful. Requeening and strengthening by the addition of brood and bees from normal colonies will enable the stricken ones to make a more rapid recovery. Stimulative feeding is helpful also. Invariably, however, prevention is more effective than cure.

## Chemical Control of Weeds

The chemical control of weeds by the use of various sprays and dusts, while not physically injurious to bees, has become so general as to cause a definite reduction in the pollen and nectar plants on many farming areas. The use of the chemical, 2,4-dichlorophenoxyacetic acid, more commonly known as 2,4-D, has resulted in the elimination of many pollen and nectar plants along highways, ditchbanks, pastures, grain fields, and waste places. Such plants as the mustards, chickweed, dandelion, certain thistles,

sweet clover, willows, and many others of importance as food sources to pollinating insects are susceptible to one or more applications of 2,4-D. Other chemicals are available for killing weeds which are not susceptible to 2,4-D. Because this practice is generally less expensive than cultivation or hand labor, one can expect the use of weed control by chemical means to become much more prevalent than at present. It may change the value of beekeeping locations and cause beekeepers to engage in migratory beekeeping practices in order to build numerically strong colonies for pollination or for honey production. The use of pollen supplements also may assume a more important role in colony management.

## Abnormal Conditions

Abnormal environmental conditions during the blooming period of certain plants may produce effects that often are confused with plant or chemical poisoning. For example, many varieties of eucalyptus in California bloom during the winter, and at times thousands of dead bees are found on the ground under the trees. Many beekeepers attribute these deaths to injurious effects of the nectar, but it seems more probable that the bees were paralyzed by cold. On two separate occasions, hundreds of dead bees were found under black locust trees in bloom. Portions of the intestinal tracts of the bees had been forced between the segments of their abdominal walls as if by some internal explosion. In warm weather, favorable to flight, bees produce a white honey of excellent quality from the bloom of the black locust with no injury to the bees. Frequently, cold windy weather occurs during the blooming period, and the injury undoubtedly is associated with some abnormal condition of this sort. Some experimental work needs to be done to indicate if bees are injured by nectar collected from blossoms exposed to frost.

### Additional References on Poisoning


Burnside, C. E. and G. H. Vansell. 1936. Plant poisoning of bees. *U.S.D.A. Circ.* **E-398.**

Eckert, J. E. and H. W. Allinger. 1935. Airplane dusting and its relation to beekeeping. *Jour. Econ. Ent.* **28**(3):590–597. Also see: *Jour. Econ. Ent.* **29**(5):885. 1936.

Eckert, J. E. 1933. Buckeye poisoning of the honeybee. *Jour. Econ. Ent.* **26**(1):181–187.

——. 1945. The effects of DDT on honeybees. *Jour. Econ. Ent.* **38**(3):369–374.

——. 1948. Present trend of agricultural chemicals and the beekeeping industry. *Amer. Bee Jour.* **88**:129–131, 143, 144.

Harvey, W. A. and W. W. Robbins. 1947. 2,4-D as a weed killer. *Univ. Calif. Agr. Ext. Circ.* **133.** Revised June 1947.

Knowlton, G. F., L. W. Jones, and W. P. Nye. 1947. An arsenic survey in Utah. *Utah Agr. Coll. Mimeo. Series* **338.**

Linsley, E. G. and J. W. MacSwain. 1947. The effects of DDT and certain other insecticides on alfalfa pollinators. *Jour. Econ. Ent.* **40**(3):358–363.

Michelbacher, A. E., W. W. Middlekauff, and O. C. French. 1947. Investigations to eliminate drift of calcium arsenate from the tomato pest control program. *Univ. Calif. Div. Ent. Mimeo. File* **3.474, 10.6.**

Potts, S. F. 1946. Particle size of insecticides in relation to application. *Jour. Econ. Ent.* **39**(6):716–720.

# XXIII. *Diseases and Enemies of the Honey Bee*

BY A. P. STURTEVANT*

HONEY BEES, living in colonies comprising large numbers of individuals, like other living creatures are subject to diseases. Because of their manner of living in crowded hives, it is almost inevitable that an infectious disease will spread within the hive, or even to other colonies, unless it is detected and an appropriate treatment is given.

## DISEASES OF THE BROOD OF BEES

Diseases of the brood are without doubt the most important of the diseases of bees. Brood diseases cause large annual losses in bees, honey, and equipment and materially add to the cost of honey production. Some of the brood diseases cause only relatively slight losses and can be disregarded to a certain extent. Others are serious, and prompt treatment is required to prevent their spread. Consequently, it is highly important that the beekeeper become familiar with infectious bee diseases and be able to differentiate them. Thus he will be able to apply intelligently the proper treatment and control measures and prevent greater losses through the untrammeled spread of contagious bee diseases.

### American Foulbrood

American foulbrood is an infectious disease of the brood of the honey bee. It is the most destructive of the diseases and the most difficult to control causing serious losses to the industry. This disease is widespread throughout the United States.[1] At times it may be found wherever bees are kept although it seems to be less prevalent in the Southern States than elsewhere. However, it is being held more or less in check in states which have adequate inspection and disease control laws.

---

*Arnold P. Sturtevant, Ph. D. Apiculturist in charge, Intermountain States Bee Culture Laboratory, Laramie, Wyoming, maintained in co-operation with the University of Wyoming. Specialist in diseases of bees and author of numerous articles and bulletins on that subject. Formerly in charge of the Tuberculin Laboratory, H. K. Mulford Company.

[1]Dadant, M. G. 1937. Prevalence of American foulbrood in the United States and Canada. *Amer. Bee Jour.* 77(9):425-427.

## Causative Organism

American foulbrood is caused by a specific spore-bearing germ known as *Bacillus larvae*. The name, *American foulbrood*, was given this disease because an American investigator, G. F. White,[2] of the U. S. Bureau of Entomology, first determined *Bacillus larvae* to be the causative organism. The honey-bee larva is its only known host. The disease is transmitted from one larva to another and from colony to colony by the resistant resting-stage spores. The spores gain access to a healthy larva through contaminated food. In the stomach of the larva spores germinate, like seeds, into the active or rod-shaped vegetative form. Then the rods grow and multiply, eventually killing the larva. After the larva is dead they also cause a typical putrefaction or decay. *B. larvae* is almost exclusively the only organism found associated with this disease. Its growth and activity apparently make conditions unfavorable for the growth of secondary invaders.

The first task of young bees is that of house cleaning although older bees may also participate in this work. In attempting to clean out dead brood in diseased colonies, the bodies of bees, especially their mouth parts and legs, become contaminated with spores of *Bacillus larvae*. A little later the same young bees perform such tasks as feeding the larvae, building the cells, ripening the nectar, and transferring it from one part of the hive to another. Thus spores may be carried from cell to cell. The honey in the brood chamber and part or all of that in the supers is almost certain to become contaminated, the extent depending largely upon the amount of dead brood in the colony. Once disease has spread generally through the brood nest the bees cease trying to remove dead brood; the colony gradually becomes weaker and finally dies for lack of enough emerging bees.

Spores may get into the food of larvae of any age in one way or another, but recently it has been found by Woodrow,[3] of the U. S. Bureau of Entomology and Plant Quarantine, that they are able to germinate and start growing only in larvae not more than approximately 2 days old. In American foulbrood, larvae rarely die until they have passed through the feeding stage, have been capped over, have spun their cocoons, and lie lengthwise in cells preparatory to transformation into pupae. It was assumed as a working hypothesis in work done by Sturtevant[4] on American foulbrood, that during the later coiled stages the sugar content of the stomach of the larva is too high for the germs to develop. It is only after this sugar is digested that the germs apparently increase suffi-

---

[2]White, G. F. 1920. American foulbrood. *U.S.D.A. Bull.* 809. Also: 1907. The cause of American foulbrood. *U.S.D.A. Circ.* 94.

[3]Woodrow, A. W. 1941. Susceptibility of honeybee larvae to American foulbrood. *Gleanings in Bee Culture* 69(3):148-151.

[4]Sturtevant, A. P. 1924. The development of American foulbrood in relation to the metabolism of its causative organism. *Jour. Agr. Research* 38(2):129-168.

ciently to kill the larva, cause the characteristic decay, and form the resting-stage spores again. In colonies already weakened by disease many larvae may be neglected and thus have a low intestinal sugar content. In such larvae the germs grow and kill the larvae while they are still coiled.

The vegetative rods (Fig. 281) and spores (Fig. 282) of American foulbrood are too small to be seen with the naked eye, it being possible to see them only under a powerful microscope. The spores are extremely resistant to sunlight, drying, heating, freezing, common disinfectants, and the germicidal action of honey. The maximum time that the spores retain their virulence has not been determined but they are known to remain alive for years in honey and brood combs.

## Symptoms of American Foulbrood

The symptoms of American foulbrood are remarkably uniform, due in large part to the fact that *Bacillus larvae* is the only organism associated with this disease. It both kills and decomposes the affected larvae. In healthy brood combs (Fig. 283), where a normal queen has been laying, there is a certain regularity in the arrangement of areas containing eggs, larvae, pupae, and emerging bees. The cappings are convex and uniform in appearance. The disease first may be suspected by the appearance of sunken, discolored, or perforated brood cappings, or by isolated sealed brood cells in areas where brood has recently emerged. In advanced cases, cells of healthy brood are irregularly intermingled with diseased cells either uncapped or with punctured or sunken cappings. This condition is spoken of as the "pepper-box" appearance (Fig. 284)

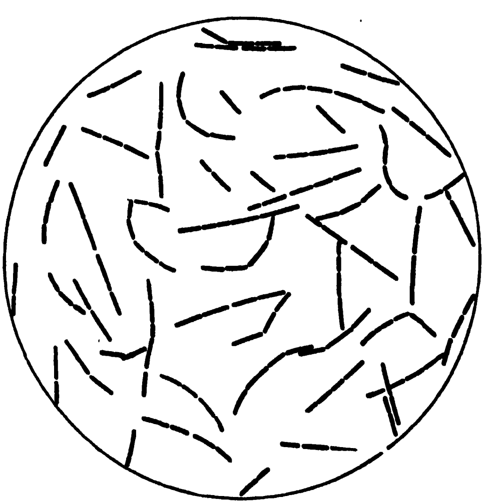


Figure 281. American foulbrood: *Bacillus larvae*, vegetative form. (From "American foulbrood," by G. F. White, *U.S.D.A. Bull.* 809, Fig. 1.)

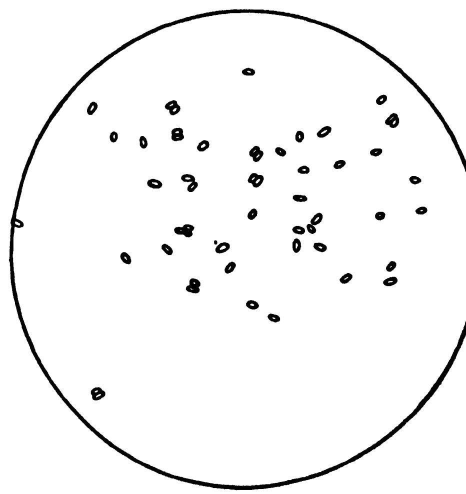


Figure 282. American foulbrood: *Bacillus larvae*, spore form. (From "Spore-forming bacteria of the apiary," by A. H. McCray, *Jour. Agr. Res.* 8(11), 1917, Fig. 5.)

Usually only worker brood is affected by American foulbrood but occasionally drone and queen brood are killed. Adult bees are never affected, but loss of brood causes an infected colony to become weaker, followed by death, usually during the winter or in the second year of the disease. Weak colonies, particularly in the spring, always should be inspected carefully for American foulbrood.

The constancy and the uniformity of all the symptoms characterize this disease more than does any one symptom. Death occurs quite uniformly after the larvae have been capped over, have spun their cocoons, and are fully extended motionless on their backs on the floor of the cells (Fig. 285). Occasionally death is delayed until after the pupa has formed and the various appendages are apparent (Fig. 286). In advanced cases neglected larvae that die while still coiled may resemble larvae dead of European foulbrood and may require a laboratory examination for definite diagnosis.

The earliest symptoms of American foulbrood, appearing at about the time of the death of a larva, may be easily overlooked. Soon after death the glistening white color of the healthy larva or pupa changes to a dull white or slightly cream color, the body wall is easily ruptured, and

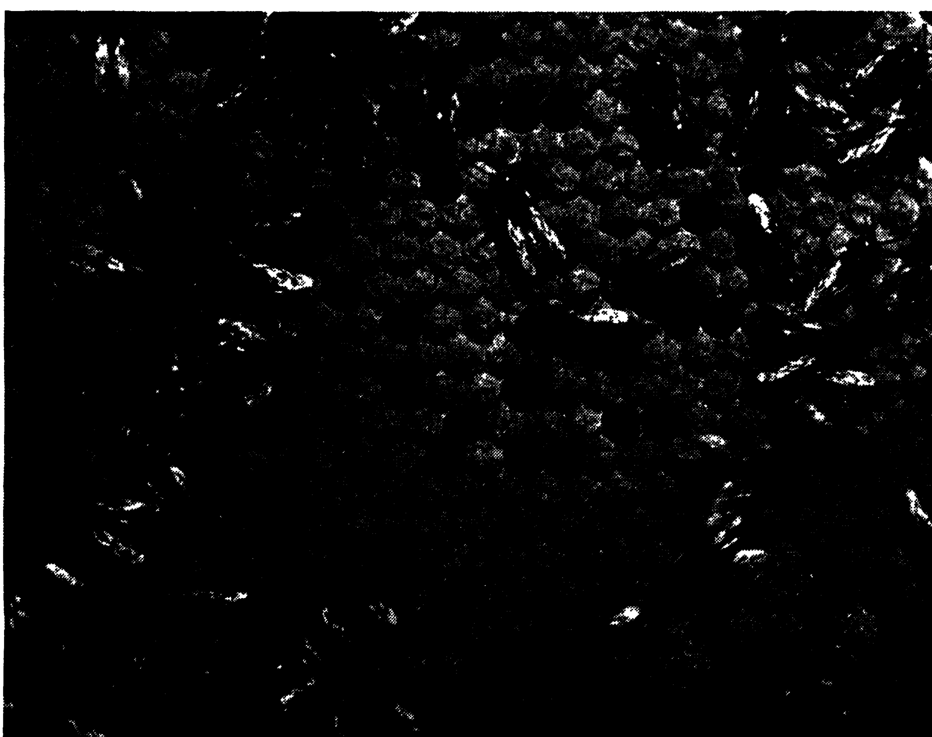


FIGURE 283. Brood comb showing healthy sealed brood at age when American foulbrood kills the brood. (*Photo courtesy Division of Bee Culture*)

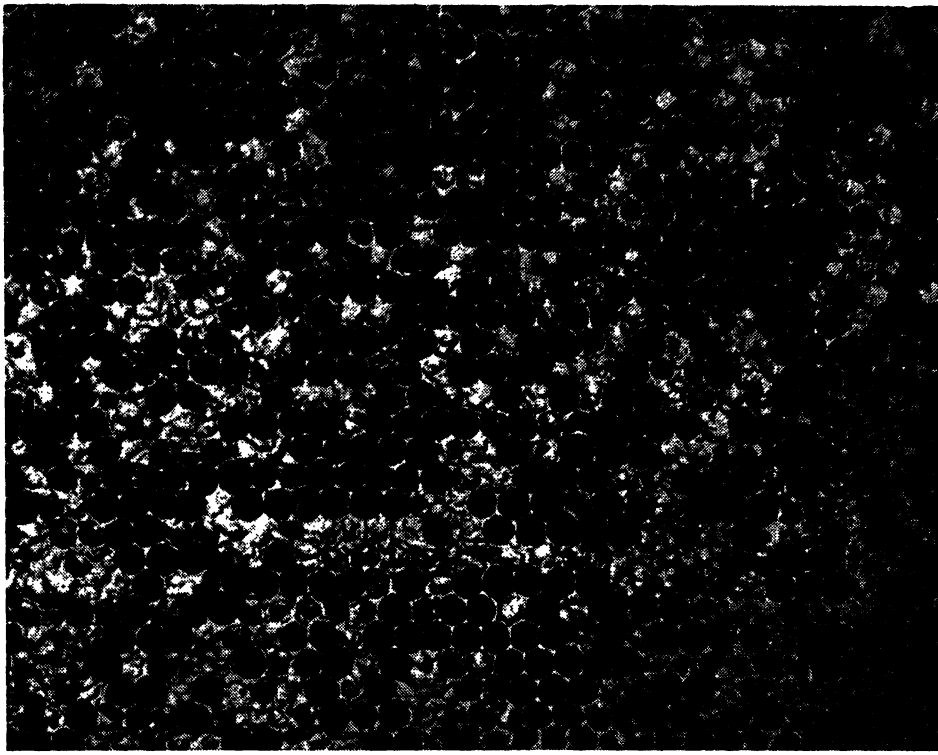


FIGURE 284. American foulbrood. Old brood comb with an advanced case of American foulbrood, showing perforated and sunken cappings and scattered appearance of sealed brood. Many of the open cells from which cappings have been removed by the bees contain scales. (From "Diagnosing bee diseases in the apiary," by C. E. Burnside and A. P. Sturtevant, *U.S.D.A.* Circ. 392, Fig. 2B.)

the tissues are soft and more or less watery. Shortly after death the well-rounded appearance is lost, the color changes to a light brown, and the consistency becomes more slimy, with a melted-down appearance. As decomposition progresses, the dead larva gradually sinks in the cell and the color changes from a light coffee color to a dark chocolate brown (Fig. 287). During the so-called ropy state of decomposition, by means of a match or toothpick, brood remains can be drawn out like thick glue into characteristic stringy or fine silklike threads (Figs. 288, 289). Typical dark brown to almost black American foulbrood scales are formed on complete drying. Drying progresses more rapidly in cells from which the cappings have been removed.

At times in old brood combs the scales are difficult to distinguish for they are about the same color as the comb. In new combs they are readily seen. The appearance and position of these scales are remarkably uniform which is a useful aid in diagnosis. They can be seen extended along the lower side walls with the rear end curved up in the bottom of the cells. Occasionally, cross markings which represent the segmentation of

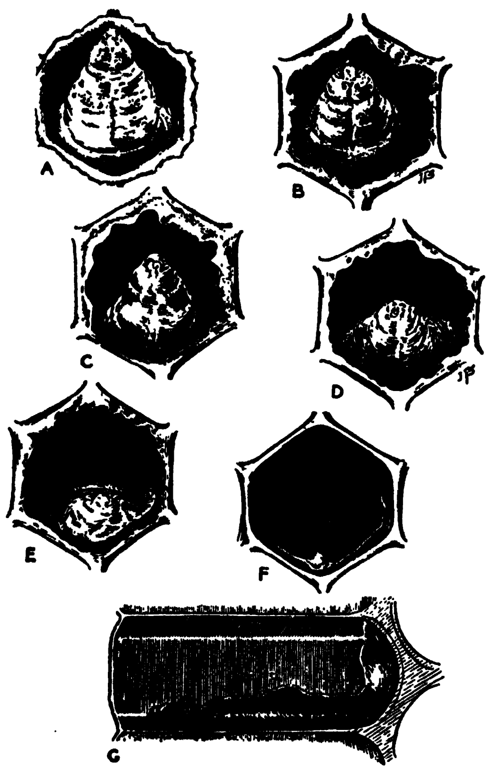



FIGURE 285. American foulbrood: Symptoms. Stages in the decomposition of larvae. *A*, Healthy larvae at the age when most die of American foulbrood. *B, C, D, E*, Progressive stages in the decomposition of dead larvae. These stages can usually be detected only by removing the cappings. *F*, Scale of American foulbrood. *G*, Longitudinal view of an American foulbrood scale. At this stage the scale is difficult to remove. (From "The treatment of American foulbrood," by J. I. Hambleton, *Farmers' Bull.* 1713, Fig. 1.)

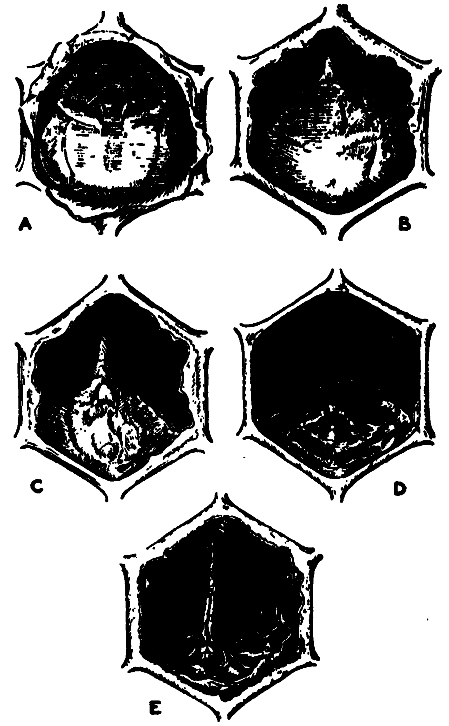



FIGURE 286. American foulbrood: Symptoms. Stages in the decomposition of pupae dead of American foulbrood. *A, B, C*, Heads of pupae showing progressive stages of melting down and decay. In B and C the tongues show prominently. *D*, Scale of American foulbrood formed from drying down of a diseased pupa. *E*, Scale of American foulbrood with vestige of tongue of pupa adhering to the roof of the cell. (From "The treatment of American foulbrood," by J. I. Hambleton, *Farmers' Bull.* 1713, Fig. 2.)

the larvae can be seen on the scales with a slight knoblike protuberance at the head end near the mouth of the cells. These characters can best be seen when the comb is held inclined so that a bright light falls on the lower side walls and into the bottom of the cells. When completely dried the scales are brittle and often adhere so tightly to the cell walls that they are difficult to remove without breaking them. When bees are active in the removal of diseased brood in slightly affected colonies, disease remains may be cleaned out before they are detected if infrequent inspections are made.

Small particles of scales in the bottoms of cells that have not been completely cleaned out may be overlooked. They are extremely difficult

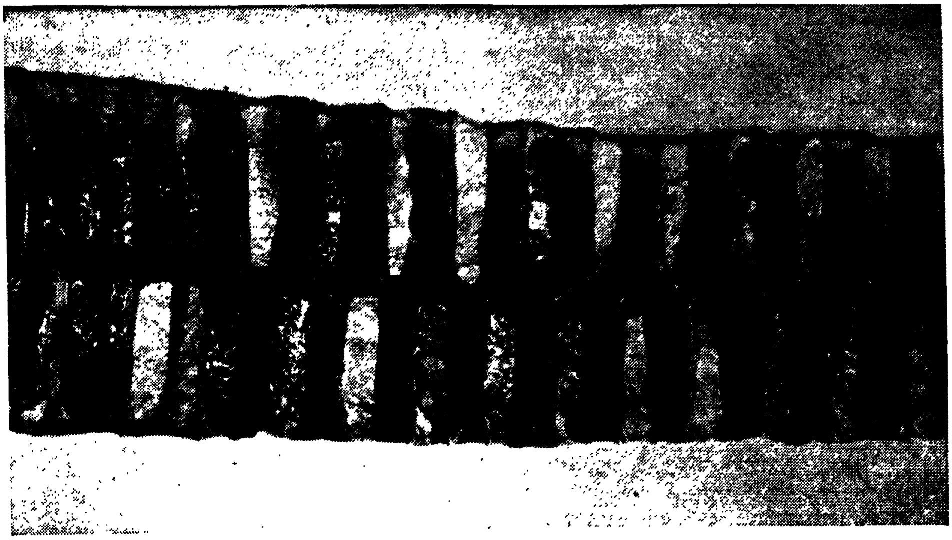


FIGURE 287. American foulbrood. Scales and decaying larvae as seen in cross section of infected comb. (*Photo courtesy Division of Bee Culture*)

FIGURE 288. American foulbrood. Typical ropiness of decayed infected larvae. Also shows scales and decaying larvae in cells. (From "Diagnosing bee diseases in the apiary," by C. E. Burnside and A. P. Sturtevant, *U.S.D.A. Circ.* 392, Fig. 7.)

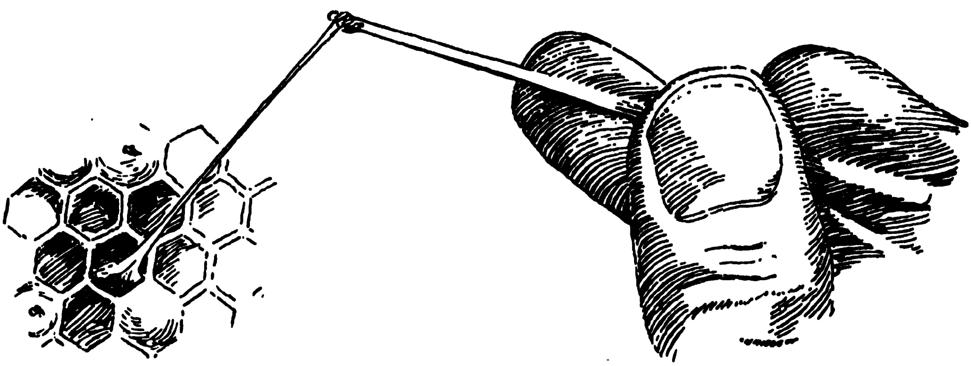


FIGURE 289. American foulbrood. The fine stringy or threadlike ropiness. (From "Control of American foulbrood," by E. F. Phillips, *Farmers' Bull.* **1084**, Fig. 2.)

to detect and identify, and doubtlessly are seldom seen in ordinary inspection. This is one reason why it is so often a difficult and prolonged task to eliminate American foulbrood from an apiary.

Pupae that die of American foulbrood undergo similar changes in color and consistency and in the final formation of the scales. Occasionally the tongue of a dead pupa will be extended from the head and will adhere to the roof of a cell as a fine thread, being easily seen as one looks into the cell (Fig. 286). This is a significant and generally reliable symptom.

American foulbrood has a pronounced characteristic fishy gluepotlike odor. In an advanced stage of disease the odor usually can be detected a foot or more from the combs when the cover is lifted from the hive.

### MILK TEST FOR AMERICAN FOULBROOD

In the course of a study on the physiology of *Bacillus larvae,* Holst[5] found that several unique enzyme properties of this organism were revealed which suggested a basis for a field test for American foulbrood. The test is intended for use of inspectors and operators having frequent need for an American foulbrood test. Materials needed are skim-milk powder, water, a small vial, and a medicine dropper.

Reconstituted milk is prepared from milk powder by adding 4 level teaspoons to a quart of water. The milk should be made up the day the tests are run to avoid souring. When only a few tests are to be made, it is not necessary that the reconstituted milk be used. Whole or preferably skim milk may be used instead. Best results are obtained if the water is warm but not uncomfortably hot. The test will work, though, at a temperature around 50° F. but slower clearing will occur.

To run the test, place a scale of American foulbrood in the vial and add 20 drops of warm water and shake gently. Then add 10 drops of

---

[5]Holst, E. C. 1946. A simple field test for American foulbrood. *Amer. Bee Jour.* **86**(1): 14, 34.

powdered-milk solution and again shake gently. If less than an entire scale is used, or if samples of ropy material are used, add 20 drops of water as before but reduce the number of drops of milk proportionately. The test is positive if the milky suspension clears, which usually occurs within 15 minutes, leaving a transparent pale-yellow liquid. With non-American foulbrood scales the liquid may become somewhat discolored, but the suspension remains cloudy during the 15 minutes of the test and the test is considered negative. It is advisable to have a check vial with only water and milk suspension for comparison.

As a matter of good practice, care should be exercised in disposing of the material in the vial after the test is run. The vials should be washed clean and boiled 20 minutes in water before re-use.

### Treatment and Control

The treating of infected colonies by the shaking method was recommended for many years. The bees from the old combs of the diseased colony are shaken into a clean hive onto clean frames containing foundation, thus giving the bees a new start in housekeeping. This treatment may reduce losses due to the disease, and a careful operator who thoroughly understands the disease and the necessary precautions may be able to maintain his apiaries in this way. However, the disease is rarely eradicated by shaking, and treated colonies are weakened to such an extent that they may have to be nursed along. The very act of shaking, if not done with extreme care, is apt to spread the disease.

It is now commonly recognized and generally recommended[6] that the safest and, in the end, the most economical means of stamping out American foulbrood is to burn the diseased colonies. While this procedure may seem wasteful to those who believe less drastic measures afford ample protection, it is the method that leaves the least opportunity for the disease to recur.[7]

Diseased colonies should be burned immediately after the infection is discovered. First, the bees must be killed. A tablespoon of calcium cyanide, which liberates extremely poisonous gas and must be handled with great care, is spread on a sheet of paper or cardboard and slipped into the entrance of the hive (Fig. 290). The bees will be killed in a few minutes. As an extra precaution additional cyanide may be thrown into the top of the hive, because occasionally the bees fall so rapidly onto the poison placed in the entrance as to prevent the fumes from penetrating to all parts of the hive. The hive entrances should be left open so that field bees which return to the hive will also be killed.

Gasoline is sometimes used to kill the bees. A pint or more is poured over the top of the frames, and the cover then closed tightly. Most of

---

[6]Hambleton, J. I. 1933. The treatment of American foulbrood. *U.S.D.A. Farmers' Bull.* 1713.

[7]Dadant, M. G. 1939. Disease eradication work in the United States. *Amer. Bee Jour.* 79(6):286.

the field bees will return within about 30 minutes and then the hive entrances should be closed.

After the bees have been killed, the contents of the hive should be burned with the least possible delay to prevent robber bees from taking any of the honey, as both calcium cyanide and gasoline act as repellents for only a short time. If the bees are killed and burned at night, the danger from robber bees will be lessened. It is essential, of course, to have everything well planned and all necessary material at hand.

Before the bees are killed, a pit 18 inches or more deep and wide enough to hold all the material to be burned should be dug in a place not likely to be plowed or otherwise disturbed. Plenty of kindling should be placed in the pit, with pieces strong enough to support the combs arranged crosswise to permit plenty of ventilation underneath, and a fire

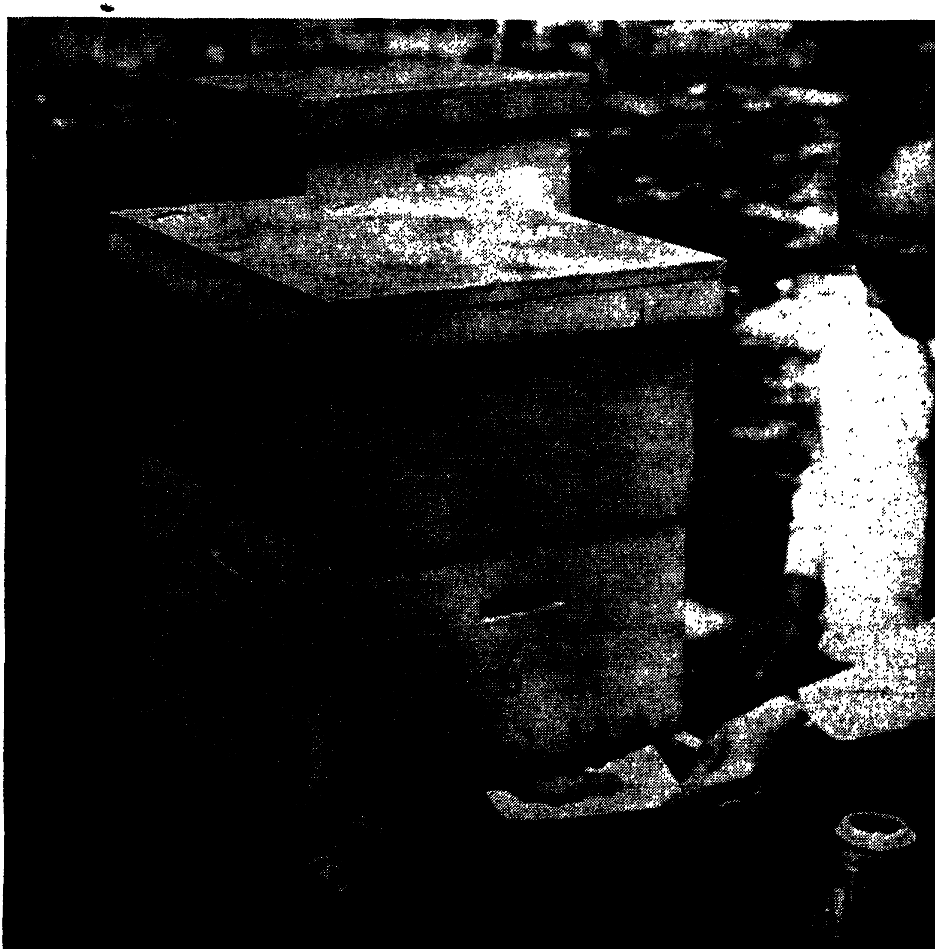


FIGURE 290. Killing bees of a diseased colony with calcium cyanide. (From "The treatment of American foulbrood," by J. I. Hambleton, *Farmers' Bull.* 1713, Fig. 6.)

FIGURE 291. American foulbrood. Proper method of burning combs from infected colonies. (Cover illustration, "The treatment of American foulbrood," by J. I. Hambleton, *Farmers' Bull.* 1713.)

kindled. To burn the brood and honey thoroughly, a brisk hot fire is necessary. The hives containing the dead bees should be carried intact close to the pit and the bees and frames fed to the fire as fast as circumstances permit (Fig. 291). The bottom boards, hive bodies, inner covers, and tops are not burned. By placing the hives on pieces of burlap or stout paper it will be easy to gather up and burn the bits of comb, honey, or dead bees which may be dropped during the operation. After everything has been completely burned, the topsoil surrounding the fire should be raked into the pit to prevent bees from healthy colonies gaining access to any dead bees or honey. The pit should then be filled.[8]

The beekeeper should not wait for an inspector to discover and burn his infected colonies, but should, himself, periodically inspect all colonies and promptly destroy every diseased one. A few colonies burned at once may prevent a general spreading of the disease throughout an apiary. If there has been any equalization of brood, if supers or combs have been transferred from one colony to another, or if diseased colonies have been robbed out, it is highly probable that the disease will show up later in other colonies. Under such conditions, even where burning is done carefully and thoroughly, it is usually at least 3 or 4 years before the disease can be stamped out in an apiary.

[8]Paddock, F. B. 1941. Control of American foulbrood. *Iowa Agr. Ext. Circ.* 212. (Revised.)

### SULFA-DRUG TREATMENT

For several years there has been a widespread interest among beekeepers in the use of sulfa drugs for the treatment of American foulbrood. Since the publication, in 1944, of the results obtained by Haseman and Childers,[9] sulfathiazole added to sugar sirup and pollen substitutes or supplements has come into rather general use for the treatment of diseased colonies. This treatment also has been advocated as a preventive measure in areas where American foulbrood has been more or less prevalent. Several articles have appeared in the bee journals reporting apparent success in the elimination of American foulbrood by this treatment. However, some reports of recurrence of disease after treatment, or even failure during treatment, have indicated that the use of sulfathiazole is not entirely successful under all conditions. Such weaknesses in this treatment could constitute a considerable danger, from the possibility of continued spread of the disease, where beekeepers depend blindly on sulfathiazole as a sure cure for American foulbrood. Furthermore, it has been found that sulfathiazole has no effect on European foulbrood.

Sulfathiazole, which comes in 0.5 gram tablets, is added to sugar sirup, according to which of the various recommendations are followed, in amounts varying from one to three tablets per gallon. Sugar sirup for feeding to colonies is generally made up of equal parts of sugar and water, although a thinner sirup is recommended for spring feeding. Since sulfathiazole is only slightly soluble in water, the tablets should be ground to a fine powder and dissolved as much as possible in a cup of hot water (not over 180° F.) before being mixed with the sirup. A completely soluble powder form, sulfathiazole sodium, is just as effective and easier to use. A scant 1/4 teaspoon is approximately equivalent to a half-gram tablet of sulfathiazole. The treated sirup can be used in preparing pollen-supplement cakes, to be given colonies before natural pollen is available. According to Haseman,[10] 4 to 8 quarts of treated sirup should be sufficient to protect a colony from infection or to enable it to clean up infection. In severe cases additional sirup may be needed. It will pay to remove some of the worst combs, render them, and replace them with full sheets of foundation or drawn combs.

The treated sirup should be fed before the main honeyflow in the spring or after the honeyflow in the fall. In large apiaries it may be desirable to place it in 50- or 100-gallon vats in the open yard, but taking precautions against robbing.

Numerous variations of this treatment have been reported by beekeepers. Cale[11] suggests that, whenever it is necessary to feed overwin-

[9]Haseman, L. and L. F. Childers. 1944. Controlling American foulbrood with sulfa drugs. *Mo. Agr. Expt. Sta. Bull.* **482.**

[10]Haseman, L. 1946. Sulfa drugs to control American foulbrood. *Jour. Econ. Ent.* **39**(1):5-7.

[11]Cale, G. H. 1946. The proper use of sulfa. *Amer. Bee Jour.* **86**(11):464.

tered colonies or spring package bees, ½ teaspoon of the soluble sulfathiazole sodium be added to each 10-pound pail of sirup. He also recommends the use of resistant-stock queens as a further precaution against disease. He believes that a constant watch should be kept for disease even when treatment is being given, and that combs from all diseased colonies should be melted.

It has been observed repeatedly, both in the apiary and under carefully controlled investigations, that the development and spread of the disease is markedly reduced when colonies are given the sulfathiazole sirup treatment. All visible evidence of disease, such as ropy larvae or scales, even may entirely disappear. In badly infected colonies the disease disappears slowly and often incompletely. The harboring of such colonies is thus a dangerous source of continued spread of the disease to other colonies.

Investigations by the Division of Bee Culture of the Bureau of Entomology and Plant Quarantine have shown that sulfathiazole is not a disinfectant or germicide and cannot destroy the spores of *Bacillus larvae* that may become incorporated in honey or that may be ingested by larvae. This observation recently has been confirmed by Katznelson of the Canadian Department of Agriculture.[12] Work at the Bee Culture Laboratory at Laramie, Wyoming, in which healthy larvae were individually inoculated with disease spores that had been subjected to various concentrations of sulfathiazole for varying periods of time, has confirmed previous laboratory work with cultures, that sulfathiazole does not destroy American foulbrood spores. However, when spores are ingested by young larvae of susceptible age along with larval food containing sulfathiazole, the germination of the spores is delayed, or if the spores are able to germinate, the active growth of the organism appears to be stopped. Thus the bees apparently are able to remove the sick or even the older dead larvae faster than newly infected larvae can develop, thereby reducing the active infection to the point of apparent recovery. This action, however, does not eliminate the danger from spores that find their way to other resting places and are unaffected even by contact with sulfathiazole. In any treatment short of burning these hidden spores must be taken into consideration.

In view of the small amount of information that we have on this new method of treating American foulbrood, the beekeeper himself must decide whether or not to feed sulfathiazole. Even though the drug may materially reduce the amount of disease in infected colonies, even to the point where no disease is visible, virulent spores may still be present in such colonies. The spores may be hidden in honey that may not be consumed for long periods, or in pollen, or adhering to the sides of cells, or on frames of hive bodies themselves, and may be entirely invisible and

[12]Katznelson, H. 1948. Sulfathiazole in relation to the organism *Bacillus larvae*, agent of A.F.B. of bees. *Gleanings in Bee Culture* 76(3):140-141,181.

harmless as long as they remain in those places. It also has been observed recently at Laramie that small parts of scales containing numerous spores, not completely removed by the bees, occasionally are covered by fresh nectar or by freshly gathered pollen. Such occurrences give false appearances of recovery and account for frequent cases of recurrences. When such hidden spores, through manipulation by worker bees, reach the intestinal tract of larvae less than 2 days old in a colony that has not been treated for some time, the infection will probably recur.

It is possible that treatment with sulfathiazole under certain conditions, such as light initial infections, may entirely eliminate the disease under the most favorable circumstances, but the chances of this occurring often are rather remote, particularly so when bees more extensively infected are not transferred to clean combs or foundation prior to treatment. A beekeeper who has fed the sulfathiazole and seen all apparent evidence of the disease disappear must decide for himself how long he will keep the apparently cured colonies under observation before he is willing to take frames of honey or brood or bees from such colonies and give them to healthy colonies. Should he keep such colonies isolated and under observation for 1, 2, 3 years or more after treatment before he is willing to lose identity of the treated colonies and their combs? It is doubtful that beekeepers will want to revert to the use of hospital yards. A hospital yard prolongs the danger of infection not only to healthy colonies belonging to the beekeeper but also to his neighbors' colonies.

Beekeepers with about a dozen hives, who can keep their colonies under frequent and direct observation, might feed sulfathiazole to all their colonies annually as a routine practice. Even then carelessness by the inexperienced beekeeper can menace the colonies of his neighbors and commercial beekeepers. It probably is not practicable for commercial beekeepers to give such intensive treatment to large numbers of colonies. It is felt by many that commercial beekeepers are taking grave chances of harboring the disease if they depend on a drug to solve their disease problem. Carelessness can well result in contaminating an entire apiary where little disease existed before and was controlled cheaply by burning. One commercial beekeeper who was relying on sulfathiazole not only increased the number of infected colonies in his own apiaries, but was directly responsible for spreading the disease in his county, to the extent that more new cases of disease developed in that one county than in the entire State.

The annual cost of routine feeding of sulfathiazole to a large number of colonies could easily surpass the annual cost of burning. Colonies susceptible to American foulbrood would be perpetuated. Even though it is unlikely that excessive amounts of the drug will find their way into commercial honey, sulfathiazole is an unnatural ingredient of honey.

The feeding of sulfathiazole unquestionably complicates the work of the bee inspectors. It is difficult or impossible for them to detect disease even when they know it is present. It is not yet known how soon after

a colony has been "cured" with sulfathiazole that it can be certified by the apiary inspector as clean.

Sulfathiazole is still very much on trial. It is not a definite cure for American foulbrood. Therefore, beekeepers should carefully weigh the benefits against the evident risks, before adopting the drug treatment.

### Care of Contaminated Equipment

Equipment to be saved should be protected from robbing bees and disinfected immediately. After the burning, the hive bodies, bottom boards, inner covers, and tops should be taken into the honey house, thoroughly scraped to remove all propolis and wax, and then scrubbed with a stiff brush, both inside and out, with a hot soap or lye solution. The scrapings should be burned and the wash water disposed of in such a manner that it is not accessible to the bees. Washing with soap and water is also the best way to remove spores from the hands, clothing, tools, and extracting equipment.

If it is not feasible to wash the hive bodies, they may be stacked seven or eight high to form a chimney, the inside walls sprinkled with kerosene and ignited. A little ventilation and fuel at the bottom of the stack will produce a hotter fire. Gasoline also can be used for this operation but extreme precaution is necessary. As soon as the inside is scorched, the fire should be smothered by placing a board cover tightly over the top. The outside of the hive bodies then should be thoroughly washed to remove all traces of honey. A gasoline blowtorch is a handy tool for scorching, but its use is rather slow.

Disinfecting solutions[13] are of only limited value in the treatment of American foulbrood. Their use is no longer recommended and has been almost completely discarded.

The maintenance of such a serious nuisance as a colony containing American foulbrood should not be tolerated. The best interests of the industry demand the prompt destruction of all such colonies. Under most conditions inspectors are justified in burning immediately every diseased colony because it constitutes a menace to all healthy colonies in the vicinity.

### Handling and Disposing of Honey from Affected Colonies

Both the combs and the honey in supers from a diseased colony are dangerous and constitute sources for spreading the disease. Where possible all should be destroyed with the rest of the colony. However, if an attempt is made to save such honey, special attention is required. At no time should it be accessible to the bees. Therefore, since no honey house, strictly speaking, is bee tight, the honey should be bottled[14] or canned as

---

[13]Sturtevant, A. P. 1926. The sterilization of American foulbrood combs. *U.S.D.A. Circ.* 284.

[14]________. 1932. The relation of commercial honey to the spread of American foulbrood. *Jour. Agr. Research* 45(5):257-258.

soon as possible, every vestige of honey washed from the outside of containers and from the extracting equipment and honey house, and the empty combs burned. Honey from brood nests never should be saved. Super honey from diseased colonies never should be fed back to bees.

Since it is often impossible to ascertain the source of honey purchased on the open market, such honey should not be fed to colonies of bees if it can be avoided. If such honey has to be used, it should be first diluted with an equal volume of water and slowly boiled for half an hour in a partly closed vessel, watching carefully to prevent boiling over. Boiled honey, however, should not be fed for winter stores.

It has been suggested, as a preventive measure, that sulfathiazole be added to sirup prepared from honey suspected of contact with American foulbrood, at the rate of ½ gram per gallon of sirup.

## Bees Resistant to American Foulbrood

For many years it was generally believed that once a colony of bees became infected with American foulbrood it was doomed to succumb to the disease if left alone without treatment. The shaking treatment and especially burning have held the disease in check but severe losses continue to occur. Because of this belief and because of the emphasis placed on treatment and regulatory control, the few cases of apparent recovery from this disease that had been reported were more or less ignored for a long time. The increasing frequency of such reports, combined with the increasing success during recent years in the breeding of plants and animals resistant to certain diseases, eventually brought to the attention of honey-bee investigators the possibility of developing strains of bees which might be resistant, if not actually immune, to American foulbrood.

As a result of a conference in September, 1934, between representatives of the *American Bee Journal*, the Iowa Agricultural Experiment Station, and the Iowa Extension Service, a search was started for colonies of bees reported to be showing resistance to American foulbrood. In 1935, a testing yard was established on the farm of Frank C. Pellett[15] near Atlantic, Iowa, to which were brought 45 colonies that were suspected of possessing some degree of resistance to American foulbrood. A program of testing was started by inoculation of these colonies with American foulbrood, and by selective breeding of queens heading colonies showing by their behavior to the inoculations that they did possess some degree of resistance. By the end of the 1936 season, the results of this work were reported by Park,[16] of the Iowa Agricultural Experiment Station; Pellett, of the *American Bee Journal;* and Paddock, of the Iowa Extension Service, as follows: "The major findings for the two seasons may be summed up

---

[15]Park, O. W. 1936. Disease resistance and American foulbrood. *Amer. Bee Jour.* 76(1):12-15.

[16]Park, O. W., F. C. Pellett, and F. B. Paddock. 1937. Disease resistance and American foulbrood; results of 2nd season of co-operative experiment. *Amer. Bee Jour.* 77:20-25, 34.

as follows: (1) Nearly half of the presumably resistant colonies tested have rid themselves of all symptoms of American foulbrood, (2) one third of the second-generation colonies have likewise eliminated all symptoms of this disease. It is concluded, therefore, that resistance to American foulbrood does exist in honey bees, that it is inheritable, and that the eventual development of a strain of honey bees highly resistant to this disease appears to be well within the realm of possibility."

Because of the widespread interest aroused by these encouraging results of the 2-years' observations by the Iowa Agricultural Experiment Station, Congress, in 1936, authorized an appropriation whereby it was possible to initiate a more extensive investigation of the possibility of developing strains of bees resistant to American foulbrood. As a result of co-operative agreements, the Intermountain States Bee Culture Field Laboratory, Bureau of Entomology and Plant Quarantine, Laramie, Wyoming, and the State Experiment Stations of Iowa, Texas, Wisconsin, and Wyoming, and later that of Arkansas, started an intensive program of testing, selecting, controlled breeding, and other studies related to the problem.

In the work on resistance, colonies from different sources headed by queens representing various blood lines which have been under observation for several generations are being inoculated with spores of *Bacillus larvae,* the cause of American foulbrood. Various methods are used with spores in numbers considered several times greater than necessary to produce disease in colonies. These experimental colonies usually respond in one of three ways: (1) The colony becomes hopelessly diseased and has to be destroyed; such colonies are less frequently observed as time goes on. (2) The disease develops to a certain extent but later the diseased larvae are removed by the bees and the colony to all appearances recovers; in a few cases there may be a recurrence the second season with a possible cleanup again. (3) The colony remains free from disease or at least the disease does not develop to the stage where it can be detected by the most careful inspection.

Those colonies that react according to (2) are considered to be showing superior transmitted resistance, more than that seen in the general run of stock, in that they demonstrate a certain degree of resistance and some control over the disease. Although they may permit disease to appear in a colony at one time or another, they are active in cleaning it out. Colonies which react according to (3) quite evidently show the most vigor in this house-cleaning activity and thus appear most valuable. It is from such so-called negative colonies that breeding queens are selected for subsequent generation testing. This process was repeated each year, each time selecting the best queens for breeders which were sent to Texas where daughter queens were line-bred and reared in isolated locations, under as nearly controlled conditions as possible. This phase of the work was carried on by Professor H. B. Parks, of the Texas Agricultural Ex-

perimental Station. While in each year's tests there was found a considerable percentage of daughter queens which showed the same characteristic with respect to resistance as their mothers,[17] the point has not yet been reached where 100 per cent of the daughters show the desired resistant characteristic.

Three strains of honey bees showing resistance to American foulbrood have been developed during the 9 years (1937 to 1945) in which investigations have been carried on with testing, selection, and breeding of succeeding generations by the natural mating method. Results obtained at Laramie and relatively similar results at Ames Iowa, indicated definite improvement in resistance in two of the strains and a less definite improvement of the third strain. Improvement was rapid at first, but later it tended to slow down at different levels somewhat below complete resistance. In 1945, some colonies, headed by queens crossbred between two of the resistant strains by natural matings, showed a definite increase in resistance and also a possible development of hybrid vigor, as indicated by increased honey production.

Since 1943, the studies at Laramie have been accelerated by the use of artificial insemination[18] in the breeding of queen bees, which makes it possible to control the parentage of the test queens. The artificial insemination phase of the work has been done at Baton Rouge, La. A notably significant improvement in the level of resistance has been observed in all three of the line-bred resistant lines since the use of artificially bred queens was started. The majority of such queens have shown as good colony performance, at least for the first year, as queens reared under natural conditions. Some of the intensively inbred queens, while showing high resistance, produce irregular brood of poor quality. However, the tests with resistant hybrids, crossed two ways as well as three ways between the resistant lines, have shown more resistance in the hybrids than in the component lines. This has been true not only with regard to increased resistance, but also with regard to the production of brood of high quality and an increased amount of honey. This again would indicate the development of possible hybrid vigor through crossbreeding.

These genetically controlled hybrids should not be confused with ordinary hybrids arising as the result of uncontrolled matings or from supersedure. If queens of controlled resistant stock are allowed to supersede promiscuously, the beekeeper will soon have only variable and unreliable stock, which has no more value in the control of disease than the ordinary run of bees.

Considerable study has been made, largely at the Intermountain States Bee Culture Field Laboratory, Laramie, Wyoming, concerning the

---

[17]Park, O. W., F. C. Pellett, and F. B. Paddock. 1939. Results of Iowa's 1937-38 honeybee disease resistance program. *Amer. Bee Jour.* 79(12):577-582.

[18]Mackensen, Otto, and W. C. Roberts. 1948. A manual for the artificial insemination of queen bees. *U. S. Bur. Ent. and Plant Quar.* ET-250. 33 pp., illus. (Processed.)

nature of this apparent character of resistance. Resistance has been attributed either to physiological resistance inherent in the larvae, or to behavior of the adult bees in removing diseased material from the comb, or to a combination of the two. Woodrow and States[19] have reported that brood from colonies having a history of resistance, as well as those with a history of nonresistance, was equally susceptible to American foulbrood when reared in badly diseased colonies. There was no evidence found of physiological resistance to the disease in honey-bee larvae, other than the decrease in susceptibility associated with their age. Using brood of known age in inoculation experiments, brood susceptibility was found to be greatest in the first day of larval life. Susceptibility decreased thereafter to the extent that larvae, inoculated more than 2 days 5 hours after hatching from the egg, did not become infected. The period of susceptibility corresponds closely with the period of mass feeding of the larvae. The failure of some brood to develop disease when reared under infectious conditions appears to be a result of the short time of larval life when inoculations must occur to produce infection and to the type of feeding at that time.

Behavior studies reported by Woodrow[20] show that diseased brood remains were actively removed by the bees in colonies of both susceptible and resistant history. It was found that the time required for the removal of this diseased material from individual cells and the ability of colonies to recover from the disease largely depend on the number of cells of diseased brood present. Light infections are overcome while heavy infections are not. In other words, recovery[21] depends in a considerable degree on the behavior character of house-cleaning activities of adult bees, which are closely related to resistance to American foulbrood.

These observations have been further confirmed by Woodrow,[22] using a new method for the controlled inoculation of individual bee larvae of known age, with known numbers of spores of *Bacillus larvae*. It was found that an individual larva, even in what appeared to be negative colonies by the former means of inoculation, is apt to become infected when inoculated by the new method. In the most resistant of these negative colonies, it was found that the bees detect diseased larvae before they can be discerned by the human eye and remove them while the causative organism is still in the growing stage, a stage in which the organism apparently is not infective. At this stage the bees can remove the source of disease without further spreading, since only spores in dead brood are infective. When adult bees show the greatest degree of resistance, they can detect

---

[19]Woodrow, A. W. and H. J. States, Jr. 1943. Removal of diseased brood in colonies infected with American foulbrood. *Amer. Bee Jour.* 83(1):22-23,26.

[20]Woodrow, A. W. 1941. Behavior of honeybees toward brood infected with American foulbrood. *Amer. Bee Jour.* 81(8):363-366.

[21]Woodrow, A. W. and C. E. Holst. 1942. The mechanism of colony resistance to American foulbrood. *Jour. Econ. Ent.* 35(3):327-330.

[22]Woodrow, A. W. 1942. Susceptibility of honeybee larvae to individual inoculation with spores of *Bacillus larvae*. *Jour. Econ. Ent.* 35(6):892-895.

the disease at the very earliest stage and keep it cleaned out as fast as a new infection develops. Thus the disease is soon eliminated. Such information gives much more concrete evidence for use in evaluating resistance to American foulbrood and in selecting queens for breeding pur poses.

A few queens of strains bred for resistance to American foulbrood have been distributed throughout the United States for experimental purposes. A large number of queens reared from resistant stock also has been used in commercial apiaries. On the whole, favorable reports have been received concerning their use, largely in prevention rather than eradication of disease. However, beekeepers should not expect that resistant stock will be a perfect insurance against American foulbrood.[23] Such strains have not yet been stabilized and are not always completely desirable for commercial beekeeping. The greatest effort has been concentrated on improving resistance to American foulbrood, although progress is being made in combining resistance with other desirable beekeeping characteristics. Some of the experimental strains are inclined to be hot-tempered, and not all of them, particularly those intensively inbred, are outstanding in honey production. The prospects of developing satisfactory controlled hybrid lines, however, are encouraging.

Beekeepers should not attempt to requeen colonies already showing disease. Even though headed by so-called resistant stock, colonies that show mild symptoms of disease should be burned immediately. The strains of bees that have been developed for several years and show superior resistance can be used, however, to help control the losses from American foulbrood,[24] especially in localities where the disease has been unusually difficult to control. Entire apiaries should be requeened to obtain the best results. All resistant queens that are superseded should be replaced by resistant stock to prevent loss of the resistant character.

Unfortunately, the development of resistance to one disease does not confer protection against other diseases. With continued inbreeding of the naturally mated, as well as with the more intensive inbreeding of artificially inseminated queens, certain of the strains of bees resistant to American foulbrood are showing susceptibility to European foulbrood. This tendency is not so pronounced in the crossbred hybrids. More intensive breeding and selection work will be necessary with these resistant lines, as well as with other new lines for which a search is being made, before completely desirable strains of bees can be developed that are resistant to both American and European foulbrood. State and Federal agencies will have to test, breed, and distribute resistant stock, since it would be difficult for private parties to finance such an extensive program.

---

[23]Hambleton, J. I. and O. W. Park. 1942. Resistant stock in advertising. Confusion of the terms "resistant" and "immune." *Gleanings in Bee Culture* 70(12):713-715.

[24]Cale, G. H. 1940. How to use resistant stock. *Amer. Bee Jour.* 80(5):210-211.

# European Foulbrood

European foulbrood is another infectious disease of the brood of the honey bee. As a rule this disease is not as destructive nor so widespread in the United States as American foulbrood. It is primarily a disease of weak colonies of common black bees and their hybrids. Its depredations are generally more severe in regions lacking an early honeyflow where colonies are unable to build up sufficiently in the spring. European foulbrood seems to be most prevalent in the North Atlantic States and in parts of the North Central States, particularly in the portions of New York and Pennsylvania where the late-blooming buckwheat is the principal source of nectar, and in regions where the honeyflow sometimes fails. The latter is true of the West Coast States, California in particular, where crops are variable because of variation in rainfall. In states near either side of the Mississippi River there seems to be considerable variation in the amount of European foulbrood, depending on the nature of the localities. There have been very few cases of this disease reported from the Mountain States, although an unexplainable outbreak was reported from parts of the San Luis Valley, of Colorado, during 1941. There seems to be comparatively little of this disease in southern states. There are potential possibilities, however, wherever there is excessive early swarming and where a prevalence of common black or hybrid bees might permit the disease to become epidemic.

FIGURE 292. European foulbrood: *Bacillus alvei* vegetative rods and typical spores. (From "Spore-forming bacteria of the apiary," by A. H. McCray, *Jour. Agr. Res.* 8(11), 1917, Fig. 4.)

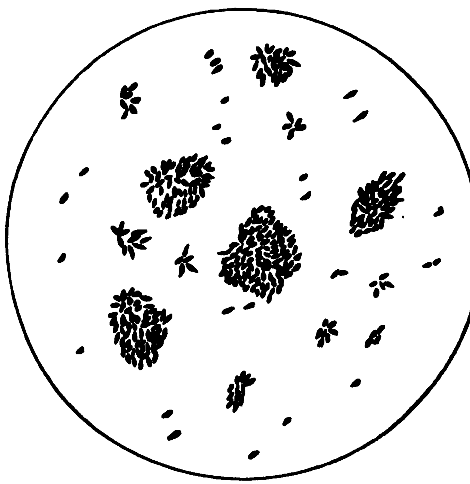


FIGURE 293. European foulbrood; *Bacillus pluton* showing characteristic lancet-shaped vegetative forms and typical grouping. (From source mentioned in caption of Fig. 292, Fig. 6.)

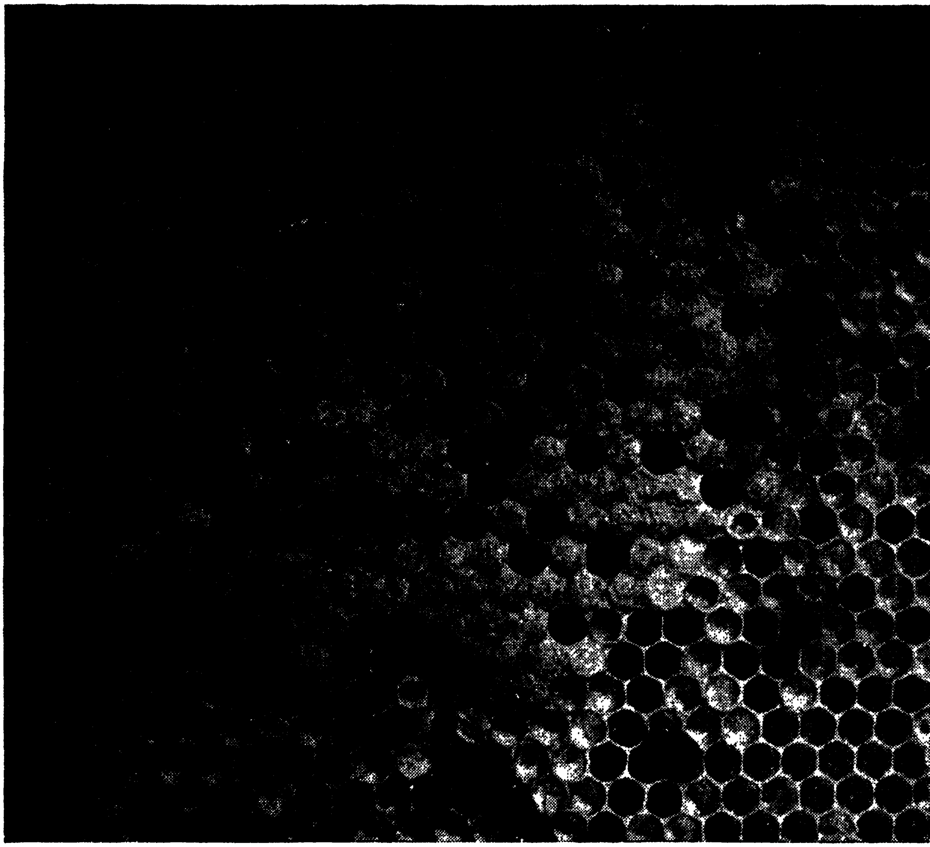


FIGURE 294. Brood comb showing healthy coiled larvae and just-sealed brood at age when European foulbrood kills the brood. Pupae are rarely affected by this disease. (*Photo courtesy Division of Bee Culture*)

The name, European foulbrood, was given this disease because it was first studied bacteriologically by European investigators, Cheshire and Cheyne, although the primary cause of the disease was determined later by White,[25] of the U. S. Bureau of Entomology.

## Causative Organism

The earliest studies on European foulbrood by Cheshire and Cheyne, in England, seemed to indicate that it was caused by a rod-shaped spore-forming bacterium, *Bacillus alvei* (Fig. 292), which is commonly found in the decayed brood, particularly in the more advanced stages of decay. It was demonstrated later by White[26] and others, however, that *B. alvei* is not the primary cause of the disease but presumably a secondary putrefactive invader. A small, somewhat variable oval or lancet-shaped, non-

[25] White, G. F. 1912. The cause of European foulbrood. *U.S.D.A. Circ.* 157.
[26] ———. 1920. European foulbrood. *U.S.D.A. Bull.* 810.

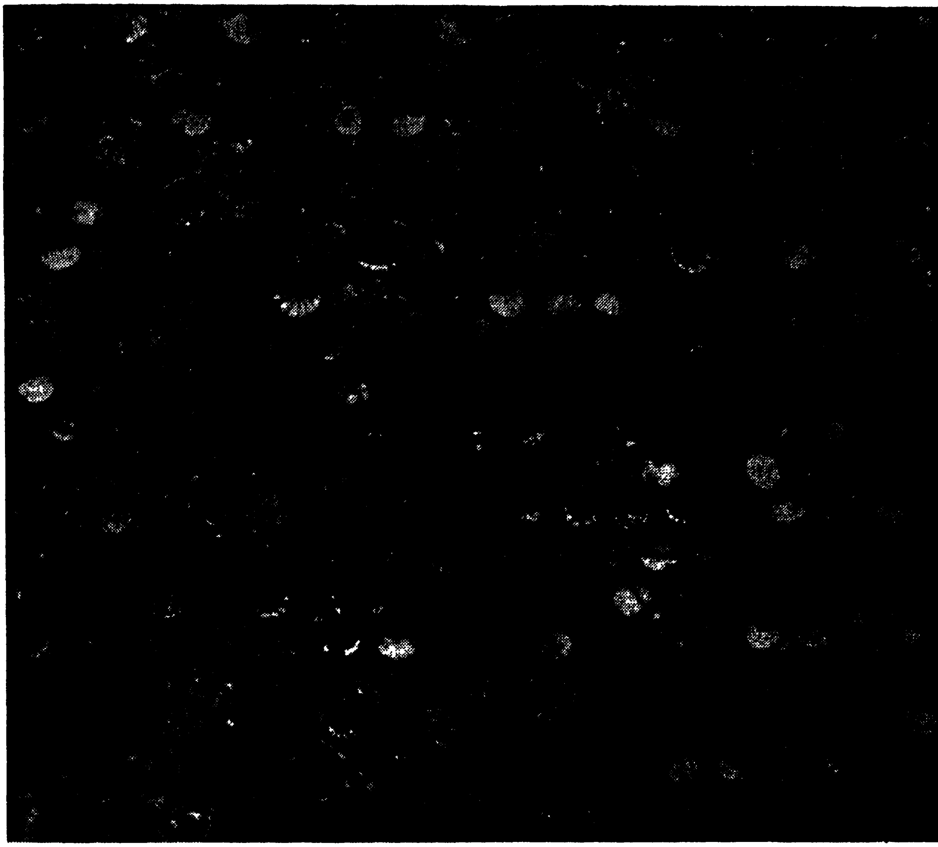


FIGURE 295. European foulbrood. Heavily infected comb showing larvae in various stages of disease and decay. (From "Diagnosing bee diseases in the apiary," by C. E. Burnside and A. P. Sturtevant, *U.S.D.A. Circ.* 392, Fig. 9.)

sporeforming bacterium (quite different from *B. alvei*), discovered and named *Bacillus pluton* by G. F. White (Fig. 293), is usually found in large numbers in sick and recently dead larvae and seems to be the active agent in European foulbrood. It has been found recently, however, by A. G. Lochhead,[27] of Canada, and also by Burnside,[28] of the U. S. Bureau of Entomology and Plant Quarantine, that the rod-shaped vegetative stage of *B. alvei* is capable under certain conditions of changing to a somewhat lancet-shaped form resembling *B. pluton,* or other forms of bacteria found as secondary invaders in larvae affected with European foulbrood. Since *B. alvei* is so commonly found associated with the disease, it is now thought that possibly *B. alvei* and *B. pluton* may be different life-phase forms of the same organism.

---

[27]Lochhead, A. G. 1929. Studies on the etiology of European foulbrood of bees. *Trans. 4th Internatl. Cong. Ent.* 2:1005-1009.

[28]Burnside, C. E. 1934. Studies on bacteria associated with European foulbrood. *Jour. Econ. Ent.* 27(3):656-668.

## Symptoms

European foulbrood is much more variable in all its symptoms[29] than is American foulbrood. This is due largely to the different ages at which larvae die (Fig. 294) and to the fact that, while *Bacillus pluton* is the primary cause of death, one or more secondary forms, especially *Bacillus alvei*, by various conditions of decomposition after death produce different symptoms.

In mild cases and in early stages of more severe cases of European foulbrood, the arrangement of the brood in the combs is not noticeably irregular. The degree of irregularity increases with the severity of the disease and the length of time it has been present. In advanced cases, open cells, which may be empty or contain eggs, or healthy or affected larvae, are irregularly scattered among cells of capped brood. Cells with discolored, sunken, or punctured cappings may be present, but these are less common than in American foulbrood. Irregular arrangement of the brood is not a dependable symptom of European foulbrood. Final diagnosis should depend upon symptoms shown by the individual dead larvae (Fig. 295).

The greater number of larvae in European foulbrood die while still coiled in the bottom of the open cells, some as early as 3 days after hatching from the egg, but many die between this age and the time of sealing, during the heavy-feeding stage. In more advanced stages of the disease many larvae may die at the age just after sealing when they would normally be moving around in the cells and spinning their cocoons, although comparatively few die after becoming fully extended. Pupae are rarely affected by this disease. The coiled and irregular positions and age of a majority of the dead brood in the cells are in marked contrast to American foulbrood.

The earliest indication of European foulbrood in sick larvae is the loss of the plumpness and glistening white color of healthy larvae. They become a flat white which soon changes to a light cream at about the time of death. Sick larvae may show abnormal movements. These often cause them to occupy an unnatural position in the cells. An elongated dull-grayish-white or yellowish-white mass often can be seen through the skin along the back of a sick or recently dead larva. This is within the intestinal tract of the larva and consists of a turbid mass that contains many bacteria. It is at this stage that the typical lancet-shaped *Bacillus pluton* forms are present, sometimes almost to the exclusion of other bacterial forms.

As the decay proceeds in a dead coiled larva, the color changes to a decided yellow or grayish brown and the translucency is lost. The yellow color, accompanied by the moist melting appearance of the collapsed

[29] Sturtevant, A. P. 1925. The relation of *Bacillus alvei* to the confusing symptoms in European foulbrood. *Jour. Econ. Ent.* 18(2):400-405.

mass, is one of the chief characteristics of the disease. When the remains have become almost dried down, the tracheae, or breathing tubes, sometimes become conspicuous again as the decomposing body tissues dry around them. Finally all that is left of the larva is a yellowish or grayish-brown saucer-shaped scale in the base of the cell, or an irregularly shaped scale on the side wall if the larva did not retain its normal position before death (Fig. 296). Scales of European foulbrood rarely adhere to the walls or bases of the cells. Being easily removed, the bees in their efforts to clean house are able to carry out a great many of them.

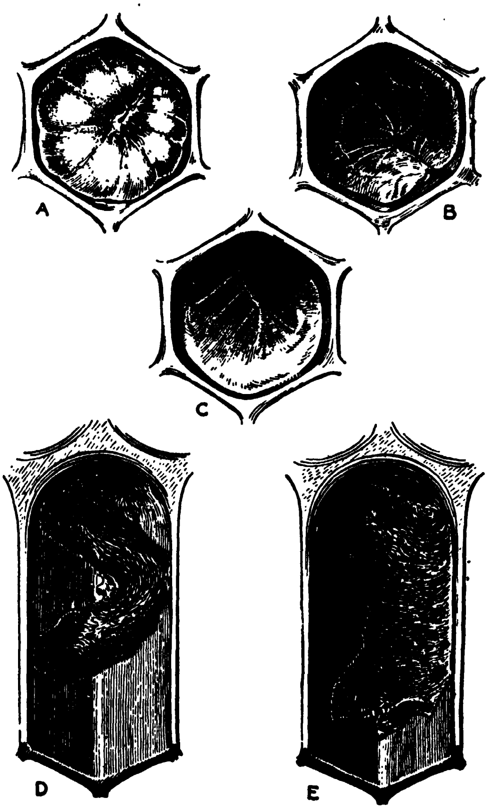



FIGURE 296. European foulbrood: Symptoms. Coiled and unsealed larvae sick or dead of European foulbrood. *A*, Healthy coiled larva at the earliest stage at which larva die of European foulbrood. *B*, Scale formed by a dried-down larva. *C*, One of several positions assumed by a sick larva prior to death. *D*, *E*, Longitudinal views of scales formed from larvae that had assumed a nearly lengthwise position at time of death, quite different from the scale shown in *B*. (From "The treatment of American foulbrood," by J. I. Hambleton, *Farmers' Bull.* 1713, Fig. 3.)

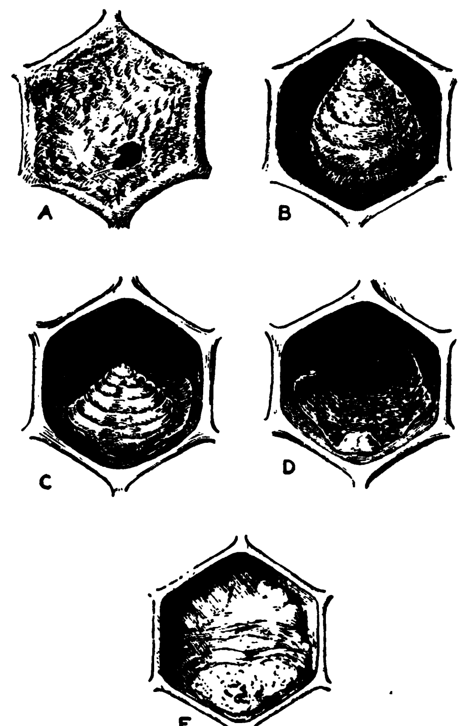



FIGURE 297. European foulbrood: Symptoms. Larvae (prepupae) which may or may not be sealed in cells and which are lying lengthwise at time of death. Stages similar in appearance to those illustrated here are encountered in American foulbrood. *A*, Sunken and perforated capping of a cell containing a dead larva. *B*, Larva lying lengthwise in the cell and recently dead. *C*, Same as *B*, except in a more advanced stage of decomposition. *D*, Scale formed by dried-down larva. *E*, Remains of a larva partly removed by the bees. (From same source as Fig. 296, Fig. 4.)

Larvae, in which death is delayed until shortly after being sealed in the cells, sometimes may become quite ropy and somewhat resemble remains of American foulbrood, except that such larvae when dried down are much more irregular in shape and position and are more easily removed than those of American foulbrood (Fig. 297). Generally in such dead larvae and scales, *Bacillus alvei* is the predominant organism, having completely overgrown *Bacillus pluton* after death of the larvae. The ropiness sometimes observed in such decaying larvae is not at all like the fine threadlike roping of American foulbrood. With European foulbrood this ropiness is coarse and lumpy. When dried into a scale it behaves more like an old rubber band which has lost its elasticity and breaks when stretched.

The odor of the early stages of European foulbrood is a sour-yeasty or sweaty smell. Because of this odor the disease is sometimes called "sour-brood" by beekeepers in Europe. In the somewhat ropy masses and rubbery scales the odor is very disagreeable, somewhat like putrefying meat. This is another feature which helps differentiate doubtful cases from American foulbrood. An important symptom is that this disease attacks drone and queen larvae as readily as the worker larvae.

### Treatment and Control

The following basic facts are of importance in consideration of the treatment and control of European foulbrood.

European foulbrood[30] is primarily a disease of weak colonies and of common black and hybrid bees. The disease is more prevalent in the spring and early summer. While at times it is observed at other periods of the year, this is not usual. It generally disappears later in the summer unless the colonies have become so weakened that they cannot remove the dead larvae. Such weakened colonies usually die in winter or in a time of dearth. The disappearance of the disease usually accompanies the beginning of the honeyflow. At this time, unless colonies have already reached maximum strength, there is a rapid increase in brood rearing and the colonies increase in strength, bringing about conditions unfavorable for the development of the disease. If the honeyflow fails, the disease may continue and under such conditions is apt to be at its worst. European foulbrood is rarely observed in regions where an early honeyflow is certain.

The earliest brood of the year in normal colonies usually escapes with little or no loss. This in all probability is due to the fact that the colonies have been able to remove most of the disease during the previous summer and there has been left only a little of the infecting material. Some bees resist the disease more successfully than others and it has been found through experience that generally the three-banded Italian bees are best

[30]Sturtevant, A. P. 1920. A study of the behavior of bees in colonies affected by European foulbrood. *U.S.D.A. Bull.* 804.

for this purpose, although Caucasian and Carniolan races have been found somewhat resistant. Resistance to European foulbrood seems to consist of a greater ability to clean house and remove the dead larvae completely. Common black bees and their hybrids do not seem to show this behavior to the same extent, and disease is practically always more prevalent in apiaries made up of such poor stock.

Since the primary causative organism in European foulbrood, *Bacillus pluton,* is not a sporeforming organism, this disease as a rule is not so difficult to eradicate or control[31] as is American foulbrood. The dead larvae do not adhere as tenaciously to the cell walls and, therefore, can be removed easily by the bees. If conditions are favorable for this house cleaning, the cells may be cleaned so thoroughly that when larvae are reared in them again disease is not contracted.

When strong colonies are headed by young vigorous queens of resistant stock, European foulbrood usually will make little or no headway, yet from time to time there may appear cases which require treatment. It is inadvisable to attempt to treat weak colonies; therefore, all such colonies should either be destroyed or united with strong colonies.

Usually the first step is to kill the old queen of a colony to be treated. In 5 or 6 days all queen cells are destroyed so that the colony is hopelessly queenless. A short period of queenlessness, during which no new brood is developing from eggs, gives an opportunity to clean out the dead and infected brood. The worker bees often do not clean out the diseased cells rapidly unless they have a queen or a queen cell. Therefore, as soon as the dead larvae are removed, the colony is given a young vigorous Italian queen of resistant stock. If only a few diseased cells are observed and if the colony is strong, a queen of resistant stock may be introduced as soon as the old queen is removed. The length of time necessary for a colony to be kept queenless varies with the strength of the colony and honeyflow conditions. On an average a 10-day period is sufficient and this may be reduced or eliminated if the colony is strong in bees and the honeyflow comes early. The shaking treatment formerly used for American foulbrood is not recommended since this treatment only tends to weaken the colony, and produces conditions favorable to the recurrence of European foulbrood.

The method of spread of disease is not well known although there is some evidence that the infection is carried by drifting nurse bees. It is known that contaminated honey is not the common means of carrying the disease since honey from infected colonies may be given to healthy colonies without danger, provided the healthy colonies are in such condition that they are able to resist the disease. It is, therefore, not necessary to disinfect honey from colonies having European foulbrood as in the case of honey from American foulbrood colonies. Neither has it been

---

[31]Phillips, E. F. 1921. The control of European foulbrood. *U.S.D.A. Farmers' Bull.* 975.

found necessary to disinfect hives, combs, or frames from diseased colonies.

While European foulbrood spreads with great rapidity, at times it does not seem to be so malignant as American foulbrood, since many colonies exposed to infection fail to contract the disease. Therefore, it appears that the control and eradication of European foulbrood depend on factors associated with good beekeeping practice: Strong colonies headed by young vigorous Italian queens of resistant stock, adequate winter stores of good-quality honey and sufficient supplies of pollen, and with proper winter protection where necessary.

## Parafoulbrood

Parafoulbrood[32] is relatively a recently identified disease of the brood of the honey bee, apparently rather closely related to European foulbrood. This disease has been found only in limited sections of a few southern states, but may be present elsewhere without having been recognized or differentiated from European foulbrood.

### Cause

This disease is caused by bacteria which resemble those of European foulbrood. In recently infected larvae the bacteria consist principally of small rods, but coccoid cells and intergrading forms soon become the more numerous. When infection is well advanced but before death and in recently dead larvae, the predominating bacterial forms usually consist principally of coccoid cells which taper at one or both ends. These vegetative forms which doubtlessly are the primary cause of the disease appear to belong to only one bacterial species. It has not been determined whether they are the same as *Bacillus pluton* or are closely related. A specific name has not been given any of them.

A spore-bearing organism which has been named *Bacillus para alvei* by Burnside,[33] of the U. S. Bureau of Entomology and Plant Quarantine, is constantly associated with parafoulbrood. This form bears considerable morphological and cultural similarity to those characters in *Bacillus alvei.* The relationship of the two forms to the diseases with which they are associated appears to be the same.

### Symptoms

Worker, queen, and drone larvae and sometimes pupae are affected but not the adult bees. The manifestations of the disease and appearance of the dead brood are similar to those of European foulbrood so a bac-

[32]Foster, R. E. and C. E. Burnside. 1933. Parafoulbrood. *Gleanings in Bee Culture* 61(2):86-89.

[33]Burnside, C. E. 1935. Studies on bacteria associated with parafoulbrood. *Jour. Econ. Ent.* 28(3):578-584.

teriological diagnosis may be necessary. The average age at time of death is usually somewhat greater than in the case of European foulbrood. Ropiness in parafoulbrood may resemble this symptom in either European or American foulbrood. A reddish-brown color of the ropy decayed brood, particularly when accompanied by the pronounced putrid odor even more intense than in European foulbrood, is sometimes a characteristic symptom. The scales can be removed easily from the cells by the house bees.

### Treatment and Control

All races of bees in North America are susceptible, but Italians appear to be more resistant than are common blacks or their hybrids. Weak colonies usually are more seriously affected than strong ones but heavy losses of brood also may occur in strong colonies. Until more is known about parafoulbrood, because of its similarity to European foulbrood, methods used for the treatment and control of European foulbrood are recommended.

## Sacbrood

Sacbrood[34] is an infectious disease of the brood of the honey bee. It is much less malignant as a rule than either American or European foulbrood. The most important point in connection with sacbrood is the occasional possibility of mistaking this disease for American foulbrood. Therefore, its differentiation from American foulbrood is necessary in order that wrong treatment will not be given.

Sacbrood is a widely distributed disease. It may be found in almost any locality where bees are kept. It may be found at times in the same colonies with either American or European foulbrood. Sacbrood may appear at any time when brood is being reared, but it is most common during the first half of the season. It generally subsides or disappears after the main heavy honeyflow has started. In ordinary cases colonies are not noticeably weakened by sacbrood. Occasionally cases are seen in which 50 per cent or more of the brood is affected. These colonies are materially weakened and the honey crop from them is greatly reduced, thereby resulting in a financial loss to the beekeeper.

### Cause

Sacbrood is caused by a so-called filtrable virus, an agent so small that it cannot be seen under the microscope and which readily passes through ordinary, bacteria-withholding porcelain filters. Infection takes place in the larval alimentary tract and a typical decomposition of the larval tissues is brought about.

---

[34]White, G. F. 1917. Sacbrood. *U.S.D.A. Bull.* 431.

### Symptoms

In colonies affected with sacbrood the brood is slightly irregular depending on the extent of the infection. One of the first indications of the disease is that the cappings over the dead brood are first punctured by the bees and one or two small holes are seen. In contrast to American foulbrood, the dark-brown head of the dead larvae may be seen through the holes in the cappings.

Death from sacbrood almost always occurs after the cell has been capped over and the larva has spun its cocoon and is motionless prior to pupation. At time of death the larvae are uniformly fully extended on the lower side walls of the cells. Thus the symptoms of sacbrood are remarkably uniform except in some of the more serious cases when some larvae die at a younger age.

In sacbrood, shortly after death of the fully extended larva, the color changes from the pearly-white to a slightly grayish-yellow color. The color gradually becomes darker, beginning with the head and front third of the larva, which soon changes to a brown or grayish brown and later to a dark brown as the larva dries down. The skin of the dead larva remains tough while the internal tissues break down into a somewhat granular watery liquid. At this stage the larva is easily removed from the cell without breaking the skin and resembles a sack of liquid, from which the disease gets its name, sacbrood. Dried-down scales of sacbrood also are

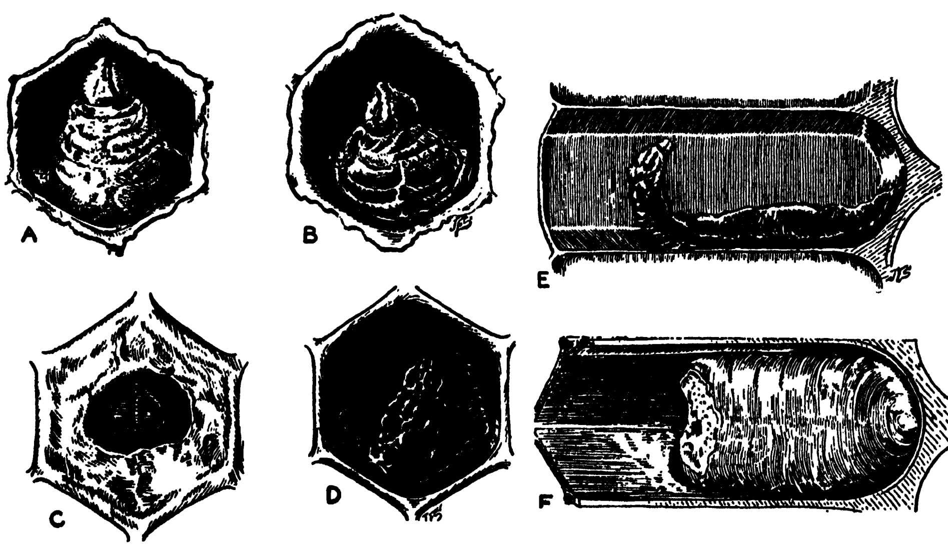



FIGURE 298. Sacbrood: Symptoms. Appearance of larvae (prepupae) dead of sacbrood. *A*, *B*, Stages in the course of the disease. *C*, The erect head end of a dead larva showing through an opening that the bees have made in the capping. *D*, *E*, Two views showing the scale of sacbrood. *F*, The head portion of this larva has been gnawed away by the bees. Note how the head remains erect in all stages. (From "The treatment of American foulbrood," by J. I. Hambleton, *Farmers' Bull.* 1713, Fig. 5.)

easily removed from the cells. They are dark grayish brown or nearly black, are hard and brittle when completely dried, and typically die with the head end turned sharply upward in direct contrast to American and European foulbrood. The lower surface of the scale takes the form of the cell walls and gives the entire scale a boat-shaped appearance, often referred to as gondola-shaped or like a Chinese shoe as shown in Figure 298.

### Treatment and Control

In most cases sacbrood will disappear of its own accord after the start of the main honeyflow. Strong colonies and good beekeeping management seem to be most effective in overcoming this disease, since the dead remains are easily removed by the bees without the disease doing much damage. Requeening with young, vigorous Italian queens, as with European foulbrood, often is effective.

## Mixed Infection

In localities where two or more brood diseases are prevalent, more than one brood disease occasionally will be found in the same colony or even in the same comb. As far as is known a single larva is never affected by more than one disease. When American foulbrood is found in the same comb with European foulbrood or with sacbrood, usually one of the diseases will be more prominent, at least in the active stages, which may cause the mixed infection to be overlooked, the beekeeper seeing only the most prominent symptoms. In cases where there is doubt or a suspicion that more than one disease may be present in the same colony, a laboratory diagnosis is desirable to prevent improper treatment. *Since American foulbrood is the most serious, a careful search for this disease should always be made even when another disease is known to be present.* Burning is the only treatment to be recommended in cases of mixed infection where American foulbrood is present.

## Fungous Diseases of Brood (Mycoses)

While the most destructive diseases of the brood of honey bees are the foulbroods caused by bacteria, some fungi, commonly called molds, cause mild brood diseases known as mycoses.[35] Brood of all ages is susceptible but fortunately fungous diseases spread slowly or not at all and epidemics never occur. A few larvae may continue to die throughout the brood-rearing season, but adult bees are prompt in removing the infected individuals and usually the beekeeper does not know that a fungous disease is present.

---

[35]Burnside, C. E. 1930. Fungous diseases of the honeybee. *U.S.D.A. Tech. Bull.* **149.**

Moist moderately warm conditions favor growth of fungi in brood in a similar manner to molds on fruit or bread. Under such conditions fungi may grow on brood combs, especially in weak colonies, and dead brood may in some instances accumulate in the cells. When fungi pathogenic for brood of bees are producing an abundance of spores outside the hive, the chances that worker bees will carry some of the spores into the hive are materially increased.

In this country fungous diseases of brood of bees are of but little economic importance. Ordinarily a very small percentage of the brood is killed, colonies are not noticeably weakened, and the reduction in the honey crop is insignificant. Sometimes in weak colonies in spring, when brood combs become moist and pathogenic fungi grow on the combs, the spores spread to the brood in considerable numbers. These colonies may be further weakened by mycoses which may be a contributing factor in the death of colonies.

### Causative Organisms

In America, the fungus that most commonly is found attacking brood of bees is the yellow-green sporeforming mold known to botanists as *Aspergillus flavus.* Related species of Aspergilli that may attack brood are *A. fumigatus* and *A. nidulans,* both of which form darker green spores.

Other fungi have been found growing on dead brood in this country but these are probably only saprophytes, which attack brood only after it has been weakened by or has died from other causes.

All of the Aspergilli grow in white threadlike masses known as the mycelium. The threadlike processes are chains of single cells, which branch profusely and eventually produce spores. When spores of one of the pathogenic forms are taken into the digestive tract of a larva, the spores germinate promptly and the developing mycelium penetrates all of the tissues. After about 2 days, provided the fungus is exposed to the air where it can obtain enough oxygen, a new crop of spores begins to form. Spores are produced in chains that grow out in numbers from a rounded head at the end of a slender stalk of the mycelium.

In Europe, a fungus called *Pericystis apis* grows over brood combs causing a disease of brood known as "chalk brood." It usually attacks only drone brood. This disease has not been found in America.

The mature fruiting bodies of this fungus are sacklike and large enough to be seen without a microscope. Each fruiting body holds a number of smaller sacks, which in turn hold the spores. The structure of the fruiting body of this fungus is the principal identifying character in this disease.

### Symptoms

Healthy larvae are glistening white but larvae attacked by Aspergilli, such as *Aspergillus flavus,* the most common pathogenic fungus in this

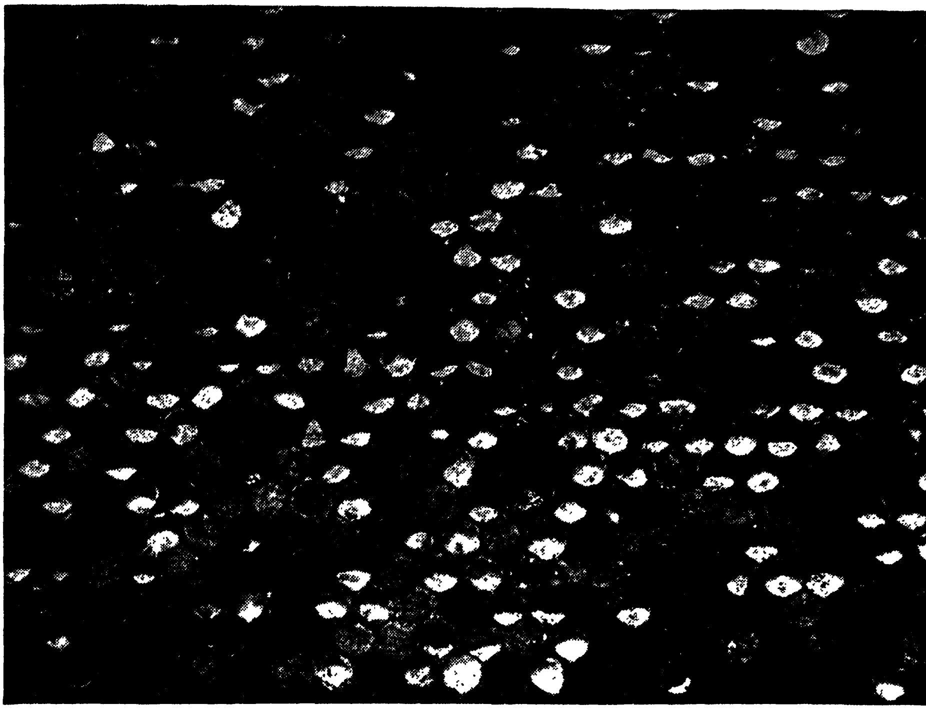


FIGURE 299. Fungous disease of the brood. Brood comb artificially inoculated with *Aspergillus flavus*, a fungus that kills the brood of bees. Dead larvae of different ages can be seen in the cells. (From "Diagnosing bee diseases in the apiary," by C. E. Burnside and A. P. Sturtevant, *U.S.D.A. Circ.* 392, Fig. 15.)

country, soon lose their glisten and become dull white. The dead larvae become noticeably hardened within a few hours. Within a day after death the larvae show shrinking and wrinkling. The fungus grows through the larval skin in a ring that resembles a collar just back of the head and then spreads over the outer surface. Spores are formed on the outer surface but are most abundant near the head. After a few days brood killed by *A. flavus* becomes very hard. For this reason the disease is sometimes spoken of as "stone brood." The completely dried brood remains are called "mummies" (Fig. 299).

### TREATMENT

Owing to their mild and transient nature, fungous diseases of brood can safely be disregarded by beekeepers when good beekeeping methods are practiced. When brood combs are kept dry, by providing colonies with good stores and the right amount of ventilation in winter and spring, mycoses will not spread within the hive. Not much can be done to prevent infection of a few larvae by spores carried into the hive by the field bees, if the conditions are right for their germination and growth.

## Purple Brood

A disorder of the brood of bees known as purple brood often appears in several of the southern states during May and June. It apparently is not an infectious disease but a condition of the brood resulting from plant poisoning.

### Symptoms

The most characteristic symptom of purple brood is the purple or blue color of the affected larvae, from which the name is derived. Death usually occurs during the larval stage, although sometimes dead pupae may be found. The shades of color vary considerably, but a purple color is usually most pronounced in the older larvae. Practically all colonies in affected localities may develop these symptoms at about the same time. Brood continues to die for about a month before the disorder subsides and finally disappears. There may be a slight to serious weakening of affected colonies caused by loss of brood. Colonies usually recover but may be so weakened as to cause a considerable reduction of the honey crop.

### Cause

Studies reported by Burnside[36] indicate that purple brood is not an infectious disease. Usually no bacteria or only a few, all nonpathogenic to bees, can be found in affected larvae. Only negative results were obtained by inoculating healthy larvae with the remains of larvae dead of purple brood. According to Foster[36] purple brood appears to be caused by poisoning from a plant which bees work for both nectar and pollen, known as southern leatherwood, also sometimes known locally as black titi, red titi, summer titi, or he-huckleberry. Foster and others have observed that purple brood occurs only where the southern leatherwood is abundant and while the bees are working that plant. Soon after the bees stop working on the blossoms, the high death rate of brood ceases and the colonies recover.

### Distribution

This plant grows principally along the edge of swamps from southeastern Virginia southward and westward to the Texas border. Purple brood has been reported as occurring in North Carolina, Georgia, Alabama, Florida, Louisiana, Mississippi, and Arkansas. It has not been reported from South Carolina, or from states outside the range of the southern leatherwood. (For additional information concerning plant poisoning, see Chapter XXII, "Injury to Bees by Poisoning.")

---

[36] Burnside, C. E. 1935. "Purple brood" of bees. *Gleanings in Bee Culture* 63(12):717-718.

# DISEASES OF ADULT BEES

Adult bees are affected by a greater variety of diseases than the brood.[37] Each of the common agents of disease, including bacteria, fungi, protozoa, and perhaps a filtrable virus, attack honey bees. Strangely enough, a most serious disease of bees is caused by another insect.

Unlike diseases of the brood, the gross symptoms shown by sick adult bees are much alike regardless of the cause. This makes it difficult to recognize the different diseases in the apiary or even to distinguish diseased bees from those that are poisoned or weakened by other causes. However, the microorganisms that attack bees can be identified with a microscope, and poisoning by insecticides can be recognized by chemical tests.

## Nosema Disease

This is probably the most widespread of all the diseases of adult bees.[38] It has been found in all the principal beekeeping regions of the world where a search has been made for it, but it is more generally distributed in some localities than in others. Nosema disease seems to be more widespread under northern climatic conditions where bees are confined to the hive most of the time during winter. It is less frequently seen in the South where bees can fly almost every day the year round. The prevalence of Nosema disease also varies with the seasons. It is usually at its worst during late winter and spring when infected bees can be found in almost every colony in some apiaries, and in heavily infected colonies all or nearly all the bees will have Nosema disease. Infection subsides as the weather becomes warmer and in midsummer infected bees may be difficult to find. Late in autumn infection may increase again but diseased bees are not as numerous in autumn as they are in spring.

Annual losses to the beekeeping industry caused by Nosema disease are considerable. Many colonies are killed outright while others are seriously weakened by the loss of many bees. Still other colonies may lose a considerable number of bees without the colonies being affected noticeably. Sometimes the disease appears in an epidemic form and then losses are particularly heavy.

Recently Farrar,[39] of the U. S. Bee Culture Laboratory, Madison, Wisconsin, found that Nosema disease is a principal factor in the supersedure of queens shipped from the South to northern beekeepers. Loss of the queen from a package-bee colony results in a nonproductive colony for the season even if it does not die out completely.

[37]Phillips, E. F. 1921. The occurrence of diseases in adult bees. *U.S.D.A. Farmers' Bull.* 975.

[38]Sturtevant, A. P. 1926. Bee diseases in the United States. *Gleanings in Bee Culture* 54(10):648-653. Also: 54(11):715-716.

[39]Farrar, C. L. 1944. Nosema disease. *Gleanings in Bee Culture* 72(1):8-9,35.

## Causative Organism

The cause of Nosema disease[40] is a microscopic single-celled animal parasite, *Nosema apis,* belonging to the Protozoa. It forms very resistant spores in one stage of its life history. The spores are small oval-shaped bodies, quite uniform in size and shape, and they have a complicated structure which places them in the group called microsporidia.

Nosema disease is transmitted when food or water of healthy bees become contaminated with Nosema spores. When spores reach the stomach of a bee they germinate promptly and young parasites are liberated. At first the young parasites grow and multiply freely within the stomach but soon they enter the epithelial cells lining the inner surface of the mid-intestine. Here they multiply enormously and produce a new crop of spores in about a week. When the thin walls of the epithelial cells break, the spores are liberated within the stomach. More epithelial cells are attacked by the new crop of parasites and soon about all of the epithelial cells are diseased. Many of the liberated spores pass on into the rectum and are ejected with the feces. By this means, spores of *Nosema apis* become scattered widely and some of them are sure to get into the food or water of other bees, thus transmitting the disease.

Spores of *Nosema apis* refract light so that they have a glistening appearance under the microscope. They resist staining by the usual dyes but can be seen clearly without staining. The young forms are less regular than the spores in shape and size. They are usually more or less oval and may be slightly elongated with rounded ends. They are not as refractile as the spores, and something of the internal structure, particularly the nucleus, can be seen under the microscope.

## Symptoms

The first noticeable symptoms shown by a colony heavily infected by *Nosema apis* are increasing restlessness of the bees and a weakening of the colony. When only a small number of bees are infected, the loss may be so gradual that it is not noticed. At other times the death rate among adult bees is very high, and the colony dwindles rapidly. The queen usually is among the last handful of bees to die.

In the individual bee the symptom most commonly observed is inability to fly more than a few yards without alighting. Many bees will be seen crawling on the ground, on the bottom board, at the entrance, and on the top of frames when the cover is removed. Sometimes infected bees crawl actively long distances from the hive, or they may crawl up blades of grass in an effort to fly. At times they collect in small groups on the ground, especially in slight depressions, in front of the hive.

It is mostly the older workers that are killed, although drones, queens, and young workers may be attacked. At times the disease seems to be

[40]White, G. F. 1919. Nosema disease. *U.S.D.A. Bull.* **780.**

aggravated by periods of cold damp weather, particularly in the spring when bees cannot fly freely. Some of the legs of the affected bees may be dragged along in crawling, as if paralyzed. The rear wings may be unhooked from the front wings and held at abnormal angles. Such bees are capable of only feeble fanning with the wings. The abdomen is often distended with feces and may appear shiny or greasy.

The stomach of infected bees is frequently swollen and whiter than normal because of the presence of many spores. In very late stages the stomach may return to normal size. The disease can often be detected in the apiary by removing the head of the sick bee, grasping the tip of the abdomen with forceps, and pulling out the digestive tract for examination. Healthy stomachs are usually brownish red, yellowish, or bright grayish white, with the circular muscular constrictions showing clearly. Heavily infected intestines are likely to be dull grayish white with some or all of the circular constrictions having disappeared. Since there is a considerable variation in the stomachs of healthy as well as sick bees, sometimes a laboratory examination is necessary to recognize Nosema disease.

### Treatment

A successful treatment for Nosema disease has not been devised, but transmission can be held in check to some extent by proper beekeeping practices. Stagnant pools or dishes of water near the hives are likely to become contaminated with Nosema spores and transmit the disease when bees gather the water. Such stagnant watering places should be removed. If water from a stream or lake is not available to the bees, running water should be provided. Colonies should have well-ripened honey of good quality or heavy sugar sirup for wintering. The size of the winter entrances should be regulated according to the strength of the colony to allow moisture from the bees to escape from the hives. These precautions also tend to prevent dysentery and Nosema is less likely to be transmitted to healthy bees within the same hive or to other colonies. A wide separation of colonies is desirable. Full sun and dryness are to be preferred to shade or partial shade with attendant dampness.

## Acarine Disease

Acarine disease, at one time called Isle of Wight disease, is not present in North America, but it is prevalent in some European countries. Adult bees of all ages are affected, and probably all races of honey bees are susceptible. In 1922, Congress passed a law in an effort to prevent the importation of the disease into the United States. According to the rules and regulations promulgated under this law only the Department of Agriculture, acting in behalf of public institutions and commercial queen breeders, is permitted to import queen bees with attendant worker bees for

experimental and scientific purposes.[41] Furthermore, importations are to be made only from such countries where no diseases exist dangerous to adult honey bees. (Nosema disease is excepted, since this disease already is widespread in the United States.) All shipments of queens and worker bees, under these regulations, are sent to the Federal Bee Culture Laboratory, Beltsville, Maryland, for examination. If the attendant bees are found to be free from acarine disease, the queens are placed in a new mailing cage with different attendant workers, and forwarded to the authorized purchaser. If acarine disease is found, the entire shipment is destroyed immediately.

Beekeeping in most European countries was seriously disrupted by World War II. Losses from acarine disease greatly increased during this war and have continued to spread since the surrender of Germany. This has been the case even in Switzerland, the country that has led in research on the mite and its control on the European continent. With these conditions in Europe, continued importations could result in the introduction of this parasitic mite into this country.

If the mite should be introduced, the disease might well endanger the entire American beekeeping industry, with attendant dangers to American agriculture, in view of the increased dependence now placed on the honey bee in the pollination of legumes and other important seed crops. If acarine disease should become established in commercial apiaries, control would be slow and expensive, particularly since the beekeepers of this country are inexperienced with the disease and the methods for controlling its spread.

Since the regulations, written in 1923, were considered inadequate, they were revoked on August 26, 1947,[42] in order to prevent any possible chance of acarine disease being introduced into this country. This revocation has the effect of prohibiting all importations of adult honey bees except such as may be brought in by the United States Department of Agriculture for its own experimental or scientific purposes. Since Canada is free from acarine disease and prohibits the importation of bees from continental Europe, this revocation does not affect the shipment of bees or queens either way across the Canadian border.

Acarine disease causes heavy losses in some localities in Europe. Once a colony becomes infested, the disease usually continues to spread until the colony dies. In the past, before beekeepers knew how to control acarine disease, thousands of colonies, including some entire apiaries, were destroyed by this disease. Losses have not been as heavy in recent years where control measures are being applied, but constant vigilance is required to prevent an infestation from spreading.

---

[41]Phillips, E. F. 1923. The occurrence of diseases of adult honeybees, II. *U.S.D.A. Circ.* 287. 34 pp.

[42]U.S.D.A. Agricultural Research Administration, Washington, D.C. 1947. Importation of adult honey bees prohibited. *Gleanings in Bee Culture* 75(10):621.

FIGURE 300. Acarine disease. Discolored trachea taken from the thorax of an infected bee. The mites that cause Acarine disease can be seen through the tracheal wall. (From "Diagnosing bee diseases in the apiary," by C. E. Burnside and A. P. Sturtevant, *U.S.D.A. Circ.* 392, Fig. 18. Also: 1921. *Bee World* 3(5), Fig. 68, *photograph by John Rennie.*)

## CAUSATIVE ORGANISM

Acarine disease of adult honey bees is caused by a very small parasitic mite, *Acarapis woodi*, Rennie.[43] The mites enter the anterior thoracic tracheae or breathing tubes through the first pair of spiracles or breathing pores,* as a rule, and, except for short periods when they may crawl out in search of another host, spend their entire life as a parasite within the tracheae (Fig. 300). The mites feed upon the body fluids of the honey

[43]Hirst, Stanley. 1921. On the mite (*Acarapis woodi*, Rennie) associated with Isle of Wight disease. *Annals and Mag. of Nat. Hist.* 8(42, 9th series):509-516.

*See: Chapter XIX, "The Anatomy of the Honey Bee," section on the "Respiratory System."

bee, taking their food from the tracheal walls. The female mites lay their eggs and the young are hatched and reared within the tracheae of their host. An infestation can be started by a single fertile female but finally the tracheae become crowded with mites. When found within the tracheae of honey bees, *Acarapis woodi* is not likely to be confused with other mites since it is the only species that parasitizes honey bees in this manner. A related species, *Acarapis externis,* lives in beehives and is sometimes found on honey bees, but does not enter the tracheae. When the tracheae become crowded, particularly after the bees die, the mites crawl out and search for a new host. The disease is transmitted by drifting of infested workers from diseased to healthy colonies and by robber bees.

### Symptoms

Bees are not injured noticeably by a few mites, but the parasites continue to breed and multiply within the tracheae until they become very numerous. The walls of the infested tracheae upon which the mites feed are injured but, if the infestation is not too heavy in the beginning, bees continue to work for weeks after they have become noticeably affected. Thus an infestation may become well advanced in a colony before the symptoms are noticeable.

When the mites become more numerous and the injury to the tracheae increases, the bees are unable to breathe normally. Heavily infested bees become weak, are unable to fly, and soon die. The weakened bees usually crawl from the hive and die. When large numbers of infested bees crawl from the hive at about the same time, which is likely to happen after a few days of rainy weather, the condition is known as mass crawling. If the original infestation is light, the disease spreads slowly at first. Since a few crawlers may not attract attention, it is possible for an infestation to become well advanced before it is noticed. Crawling may come on gradually when the disease spreads slowly but when it spreads rapidly mass crawling results. Mass crawling may free a colony of most of the weakened bees and the colony may appear to recover temporarily. After a time mass crawling may occur again, the colony becoming weaker until all the bees have died. Crawling bees frequently have swollen abdomens and unjointed wings.

The tracheae in healthy bees are pure white. Where mites feed on the tracheal walls in heavily infested bees the tracheae become blackened or bronzed in irregular spots (Fig. 300). These spots can be seen readily under a hand lens that magnifies 8 or 10 times. This is one of the symptoms used to diagnose acarine disease. The mites can also be seen readily with a hand lens. They crawl out of the tracheae soon after bees die. To examine the tracheae of suspected bees for mites, the head and forward part of the thorax are pulled out or pulled away. This brings into view the first pair of thoracic tracheae which are the ones inhabited by mites in acarine disease. While this disease has not been found in America,

samples of bees with puzzling symptoms should be submitted for laboratory diagnoses.

## Treatment

When acarine disease was first observed to be causing such heavy losses, neither the cause nor a means of controlling the disease was known. For a time there was much confusion as to the cause. *Nosema apis* was thought by some to be the organism responsible for the losses but this was doubted by others. When the real cause was found to be a mite, experiments were immediately started to control the disease. Various remedies were tried. The so-called "Frow treatment,"[44] devised, in 1927, by Richard Frow, an English beekeeper, has been adopted generally in Europe to combat acarine disease. By this remedy certain volatile chemicals are allowed to vaporize within the hive containing the infested bees. The treating material is made up as follows: safrol oil (oil of sassafras), 1 part; nitrobenzene, 2 parts; and gasoline, 2 parts. This material is poured onto an absorbing pad placed either under the frames or on top. The dosage varies from one good-sized drop given on alternate days to as high as 40 to 60 drops, depending on the temperature. The mites as well as the infested bees are killed, but healthy bees are not harmed if the proper concentration of gas is obtained. A colony usually has to be treated more than once to destroy all the mites. Since hive odors are covered up by the odor of these chemicals, precautions against robbing should be taken. Methyl salicylate[45] has been advocated to get away from this danger.

Some European investigators have concluded that nitrobenzene alone is just as efficient in the control of mites as is the Frow formula, of which nitrobenzene is a part. It is believed by these authors that the mites are not killed directly by the fumes given off by the chemicals, but by their food, the tracheal respiratory fluid which is poisoned by the nitrobenzene.[46]

A different treatment has recently been suggested by an investigator in Czechoslovakia.[47] The sealed-brood combs are taken out of all colonies in the disease area while the queens are actively laying during the honeyflow, and put into a room heated to 35° C. (95° F.) for the brood to emerge. New colonies are then prepared with these young bees and newly reared queens, and kept in a cellar at 25° C. (77° F.). The bees remaining in the old hives are sulfured, and the new colonies are not set out until all old bees in the area have been destroyed. This method is

---

[44]Illingworth, L. 1928. The Frow treatment for acarine disease. *Bee World* 9(11):176-177.

[45]Angelloz-Nicoud, M. E. 1930. Treatment of acarine disease with methyl salicylate. *Bee World* 11(3):26.

[46]Clout, G. A. 1947. Some notes on the treatment for acarine disease. *Bee World* 28(5):43.

[47]Svoboda, Jaroslav. 1947. The mechanical eradication of acarine disease. *Bee World* 28(5):41-43.

based on experiments conducted in Switzerland by Morgenthaler.[48] He showed that the emerging bees are not infested; that combs, pollen, and honey from diseased stocks do not carry the infestation; that only live diseased bees transmit the disease by close contact, thorax to thorax; and that bees over 9 days of age are completely safe from infestation.

## Septicemia

This is a recently recognized disease of adult bees that has been identified in bees from several of the principal beekeeping sections of the United States. It also has been reported from abroad. Queens and drones as well as workers become infected. Septicemia is not a very serious disease. A few bees are killed from time to time but the losses are rarely extensive enough to attract attention unless conditions favor its transmission. Diseased bees in small numbers usually can be found at any time of the year if a search is made.

The weakening effect upon colonies is ordinarily very slight and not perceptible, while the effect upon the honey crop is insignificant. The losses are probably about comparable to those caused by sacbrood and therefore not serious enough to cause beekeepers much concern.

### Cause

Septicemia of honey bees is caused by the growth of a bacterium, *Bacillus apisepticus,*[49] in the blood of infected bees but it is only slightly infectious. The bacterium requires moist conditions for growth and transmission, and is soon killed by drying. It occurs in colonies, in moist soil near infected colonies, and in water that has been in contact with bees killed by septicemia. The usual means of transmission seems to be through contaminated water. Bees that become wet with water from the soil, particularly about hives, may become infected.

Infection is not produced when *Bacillus apisepticus* is taken into the digestive tract of bees with food or water but, when a small drop of a water suspension of the organism is placed over a spiracle (opening to the breathing tube), infection follows promptly. This is thought to indicate that septicemia is transmitted through the breathing organs. There are also several other species of bacteria and yeasts that cause septicemia when placed in the blood of bees, but only *B. apisepticus* attacks uninjured bees, appearing as small spherical cells in sick bees. After the bees die some cells may become short rod shaped. In culture the majority of the cells are short rods. Young cells of *B. apisepticus* are actively motile but they become motionless after a few days.

---

[48] Morgenthaler, O. 1932. Ein Jahrzehart Milben Krankeit der Honigbiene. *Ztschr. f. Agnew. Ent. Beihefte.* 19(3):449-489.

[49] Burnside, C. E. 1928. Septicemia of the honeybee. *Trans. Fourth Internat. Cong. of Ent.* 2:757-767.

### Symptoms

Infected bees soon become weak and are unable to fly. Sick bees usually crawl from the hive or are carried out by healthy ones. Their movements resemble those of chilled bees and gradually become slower until death occurs. Before death the blood loses its clear pale-brown color and assumes a milky appearance owing to the presence of many bacteria. The dead bees decay rapidly. The muscular tissue becomes soft and pasty and has a characteristic putrid odor. Within about 2 days the body, legs, wings, and antennae fall apart when the bees are handled.

### Treatment

Septicemia is not serious enough to require special treatment. Since moisture favors spread of the infection, the small losses that occur under wet conditions can be reduced by selecting well-drained apiary sites exposed to direct sunlight for at least part of the day.

## Amoeba Disease

Amoeba disease of adult honey bees was first reported in Europe in 1916, but the causative organism was not determined until 1926, by Prell.[50] It was first found, in 1927, in this country in two colonies of bees at the Bee Culture Laboratory, Somerset, Maryland.[51] It has been found since in bees from other parts of Maryland and several other states. When amoeba disease was first recognized in Europe, the same bees had Nosema disease. It was suspected that the two diseases were in some way related. In this country, however, amoeba disease on several occasions has been found in bees that did not show Nosema spores.

Amoeba disease seems to be of minor importance in this country. The infected bees probably are injured but so few are infected that their loss is almost or entirely negligible. In Europe, however, it is considered that amoeba disease may be extremely serious, especially in conjunction with Nosema disease epidemics.

### Causative Organism

As the name implies, amoeba disease is caused by a one-celled animal parasite known to scientists by the difficult name of *Vahlkampfia (Malpighamoeba) mellificae*. It invades the Malpighian tubules of adult honey bees where it is sometimes seen in large numbers in infected areas. Both the vegetative cells and cysts (resting stage) have been seen in bees, but the life history of this parasite is not fully understood. The cysts have

---

[50]Prell, H. 1926. The amoeba-disease of adult bees: a little-noticed springtime disease. *Bee World* 8:10-13.

[51]Bulger, J. W. 1928. *Malpighamoeba* (Prell) in the adult honeybee found in the United States. *Jour. Econ. Ent.* 21(2):376-379.

thick walls and are nearly spherical. Vegetative cells have thinner walls and are slightly larger than the cysts.

### Treatment

Amoeba disease is principally of biological interest. No treatment is known and none is required since the losses are negligible.

## Fungous Diseases of Adult Bees

It was reported many years ago from Europe that a disease of adult bees is caused by a fungus. A few years ago a study was made to determine if fungi also cause diseases of bees in the United States. It was found that the same fungus, which attacks adult bees in Europe, and also several other species attack adult bees in America. These diseases attack workers, drones, and queens. While they are quite widely distributed, their spread appears to be kept in control by natural means. An occasional infected bee may be found in any colony, but infection does not spread within the hive except when combs remain damp for a considerable time and a pathogenic fungus grows over them. Bees may become infected when spores become mixed with their food or water, or when they come in contact with the fungus and later swallow some of the spores that cling to their mouth parts. Sick bees usually leave the hive before they die and do not cause other bees to become infected.

Losses of adult bees caused by fungi are not of much economic importance but are somewhat greater than those caused by mycoses of the brood. Significant losses may occur in winter or spring when the fungi grow on combs, frames, or dead bees within the hive, but infection subsides as soon as the bees can fly freely and the hive becomes dry.

### Causative Organisms

The fungus that is most commonly found attacking adult bees is *Aspergillus flavus,* the same species that attacks brood. Several species that have never been reported attacking brood may cause disease in bees. Those known to attack adult bees[52] are *Aspergillus flavus, A. effusus, A. parasiticus, A. flavus-oryzae, A. fumigatus, A. nidulans, A. ochraceus, Saccharomyces apiculatus, Mycoderma cerevisiae,* a species of *Torula,* and *Mucor hiemalis.* Some of the more virulent Aspergilli attack bees over a wide range of temperatures. Other fungi seem to require cool, moist conditions. *Mucor hiemalis,*[53] a fungus closely related to black bread mold, only attacks young bees at room temperature (about 68° F.).

The fungi that attack adult bees usually produce a filamentous mycelium, with the exception of yeasts, Torulae, and to some extent *Mucor*

---

[52] Burnside, C. E. 1930. Fungous diseases of the honeybee. *U.S.D.A. Tech. Bull.* 149.

[53] __________. 1935. A disease of young bees caused by Mucor. *Amer. Bee Jour.* 75 (2):75-76.

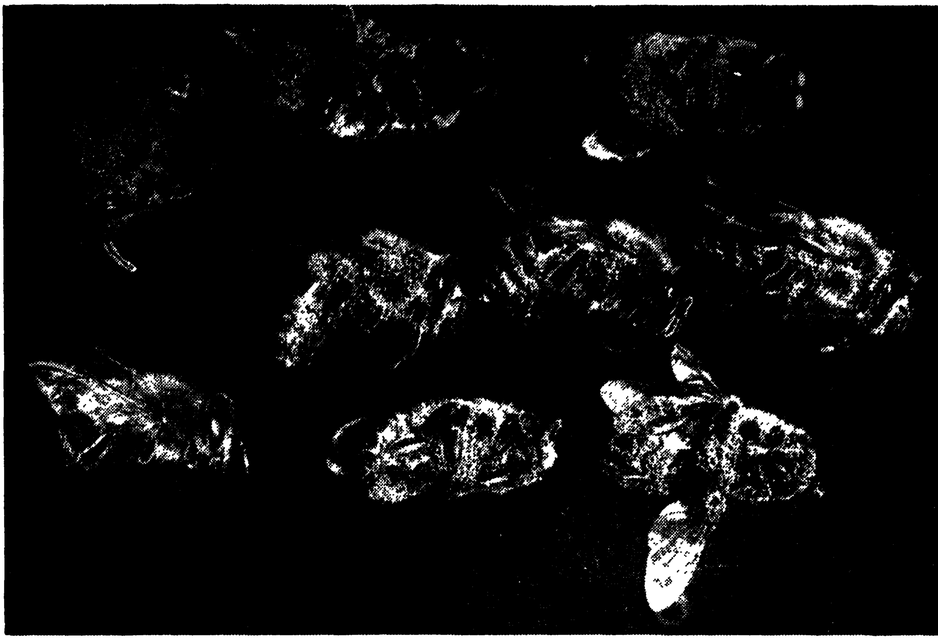


FIGURE 301. Fungous diseases of adult bees. Adult workers and a drone bee killed by *Aspergillus flavus*. Spores of the fungus are seen on the bodies of the bees. (From "Diagnosing bee diseases in the apiary," by C. E. Burnside and A. P. Sturtevant, *U.S.D.A. Circ.* 392, Fig. 20.)

*hiemalis* which grows by budding, followed promptly by separation of the cells. The Aspergilli are identified by the manner in which the spores are produced. Stalks grow from the mycelium and bear rounded terminal heads. Short, radiating, usually crowded stalks grow from the heads. Spores are formed in chains on the ends of these heads. The yeasts are identified by their manner of budding and separation of the parent from the young cells. *Mucor hiemalis* produces a rounded sacklike head on a slender stalk. The spores, contained within the head, vary widely in size. For definite identification of these fungi, the reader is referred to their technical descriptions in works of mycology.

## SYMPTOMS

There is considerable similarity in the symptoms shown by adult bees when attacked and killed by a fungus, regardless of the species concerned, consequently only general symptoms are given here. The first noticeable symptoms are weakness, restlessness, and inability to maintain flight. Sick bees usually fly or crawl from the hive and die a considerable distance away, but some bees may die in or near the hive when conditions prevent them from getting farther away.

The abdomens of infected bees increase in firmness. This often can be detected before they die. After death the firmness increases, but it is

unsafe to depend on this symptom for more than 1 or 2 days, since non-pathogenic fungi may produce similar symptoms in dead bees. Under moist conditions pathogenic fungi continue to grow on dead bees. Those with filamentous mycelium produce spores on the outer surface (Fig. 301). Under dry conditions spores may be produced only within the bodies of the dead bees. Fruiting bodies can be obtained by placing dead bees in a moist chamber at room temperature for a few days.

### Treatment

Fungous diseases are ordinarily not important enough to require special treatment. With good beekeeping practice they can be disregarded safely. Colonies should be provided with well-ripened honey for winter and allowed enough ventilation to keep the combs dry. Since the same fungi that attack bees grow on a variety of vegetable and animal matter outside the hive, a few bees are sure to become infected from time to time, but this source of infection is not likely to become serious.

## Paralysis

The term "paralysis" has long been used to designate a disorder of honey bees which seems to be widely distributed in America as well as in foreign countries. It may have been applied to more than one disorder of bees, since it is not known how many types of paralysis may affect bees. The common form of this disorder appears to be more prevalent and virulent in warm than in cold climates. In the South it sometimes spreads, affecting many colonies and causing considerable loss in bees, surplus honey, and wax. In the Northern States it usually remains confined to one or a few colonies in an apiary and often disappears of its own accord. When paralysis occurs in such mild form that only a few bees are lost, the infected colonies may store a normal crop of honey. All races of bees in America are susceptible, worker bees being chiefly affected.

### Cause

The cause of paralysis has been unknown for many years. Burnside[54] in preliminary work at the Bee Culture Laboratory of the Bureau of Entomology and Plant Quarantine, Beltsville, Maryland, found that paralysis can be transmitted in various ways from sick or recently dead bees to young healthy ones. He concluded that paralysis is infectious. None of the microorganisms found in sick bees appear to be the cause of the disorder. Butler[55] in England repeated Burnside's experiments, with similar results, and likewise concluded that there is a form of paralysis that is infectious.

---

[54] Burnside, C. E. 1933. Preliminary observations on "paralysis of honeybees." *Jour. Econ. Ent.* 26(2):162-168.

[55] Butler, C. G. 1943. Bee paralysis, May-sickness, etc. *Bee World* 24(1):3-7.

Recent work at Laramie by Burnside[56] has shown that at least one type of paralysis is caused by a filtrable virus. Viruses are so small that they cannot be seen under a microscope and can pass through porcelain filters that hold back ordinary bacteria. He was able to infect healthy bees and produce typical paralysis symptoms with a water extract prepared from sick bees that had been passed through a bacteria-withholding filter one or more times. Infection was caused by wetting the bees with this extract or by mixing it with their food. Other experiments showed conclusively that the infectious agent is a filtrable virus.

### Symptoms

During the early stages of paralysis the bees appear nearly normal and are difficult to distinguish from healthy bees. They can be detected since the healthy bees often tug and pull at them in an excited manner. The sick bees do not try to defend themselves, but may offer food. Some sick bees may crawl into a corner of the hive or onto the top bars and die, or they may crawl from the hive and die on the ground near the entrance. Others are carried out by the healthy workers. Some affected bees die quickly, whereas others linger in a weak stupor for days, becoming partially hairless before they die. Still others possibly may recover and resume their normal duties, although this has not been definitely determined.

The abdomens of sick bees may be swollen or shrunken but are usually of normal size. The bees that die quickly retain most of their hairs, but those that linger in a weakened condition may lose most of their hairs by the time of death. Loss of hairs seems to be caused by healthy bees pulling them out.

The most characteristic symptom of paralysis of a honey bee is weakness, accompanied by trembling, sprawled legs, and wings. Partial hairlessness, or a dark, shiny, or greasy appearance of the abdomen and thorax with occasional swelling of the abdomen—symptoms which many bee experts have used as signs of this sickness—occur less often than other signs. When sick bees come to rest, especially those on the top bars of the brood chamber, they sometimes begin trembling when disturbed.

### Treatment

A constantly dependable treatment for paralysis has not been devised. All the races of bees in America seem to be affected in about the same degree. However, a constant characteristic of the disorder is for certain individual colonies to be much more seriously affected than the majority of other colonies of the same race. This may indicate a difference in resistance among individual colonies. One method of treatment, based on this apparent difference in resistance, is to requeen all affected colonies

[56]Burnside, C. E. 1945. The cause of paralysis in honeybees. *Amer. Bee Jour.* 85(10): 354-355, 363.

with young queens of good vigorous stock from a colony or, better still, from an apiary in which paralysis has not occurred. Paralysis usually disappears from the requeened colonies but sometimes it continues to affect the young bees of the new queen.

The strengthening of weak affected colonies by interchanging locations with strong healthy ones has been suggested as being helpful in eliminating the disease. In this way bees from the strong colonies enter and build up the populations of the affected ones with vigorous healthy bees, which will be able to dispose of the infected bees by dragging them out and away from the hives.

## Agencies for Diagnosis

There are at times cases of death of the brood of bees or the adult bees where the manifestations of the symptoms are not clear or are confusing. The cause of death even may not be due to disease but may be from such natural causes as starvation, chilling, suffocation, or overheating, or be the result of poisoning of some type. In such cases a more complete diagnosis in the laboratory than can be made in the field is desirable in order that proper treatment and control measures may be taken.

A few states have facilities for making such laboratory diagnoses. The Bee Culture Laboratory of the U. S. Bureau of Entomology and Plant

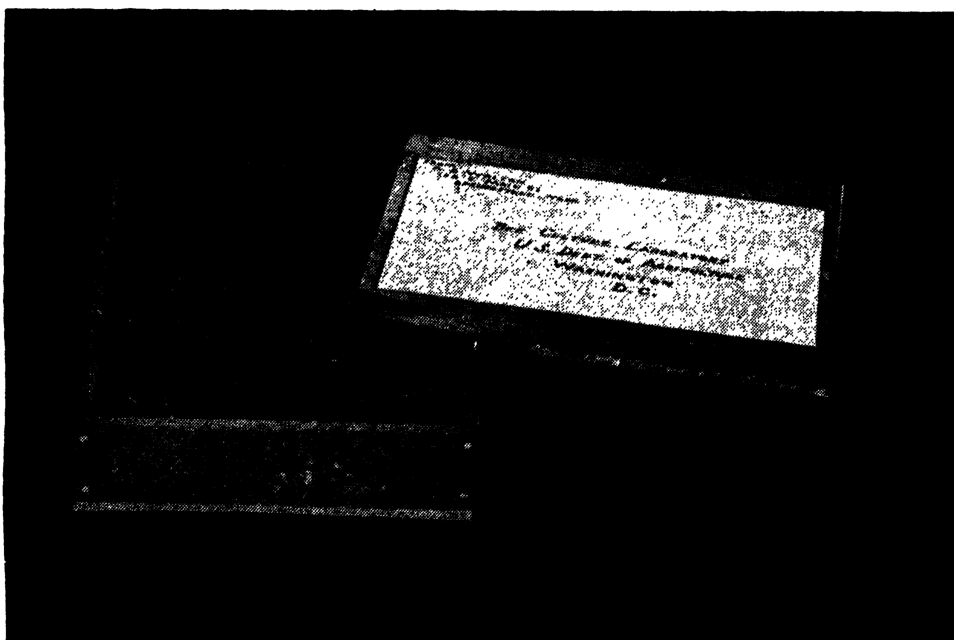


FIGURE 302. How to send a sample of brood comb for laboratory diagnosis. (From "Diagnosing bee diseases in the apiary," by C. E. Burnside and A. P. Sturtevant, *U.S.D.A. Circ.* 392, Fig. 21.)

Quarantine probably is the best equipped for this type of work. If the nature of the disease is not apparent or in case of doubt, samples of brood comb or of adult bees should be sent to the State Bee Inspector or sent addressed to the *Bee Culture Laboratory, Bureau of Entomology and Plant Quarantine, Beltsville Research Center, Beltsville, Maryland.* The sender's name and address should be written plainly on the box. If the sample is forwarded by an inspector, his name and address also should appear on the box (Fig. 302).

In sending samples of brood for laboratory examination the following instructions should be followed: (1) Cut a sample of comb at least 4 or 5 inches in size. (2) Be sure that the sample contains as much of the dead or discolored brood as possible. (3) *No honey should be present,* and the comb should not be crushed. (4) Mail the sample in a wooden or strong cardboard box. *Do not use tin, glass, or waxed paper, as these promote growth of molds.*

Smears of dead brood on paper or matches and small crushed pieces of comb are frequently unsatisfactory for diagnosis but will be examined in case the foregoing instructions cannot be followed.

If samples of adult bees are sent the following instructions should be followed: (1) Select, if possible, bees that are sick or recently dead; bees that have been dead for some time are not satisfactory for examination. (2) Send at least 50 bees in a sample; if poisoning by arsenicals is suspected, 200 or more bees will be needed for analysis. (3) Send bees in a wooden or strong cardboard box, *not in tin or glass.*

## ENEMIES OF BEES

There are several enemies of bees most of which as a rule only do occasional and minor damage, such as the bee louse, skunks, ants, wasps, mosquito hawks or "devil's darning needles," robber flies, toads, and some birds. However, the wax moth is an important enemy which may cause serious economic losses.

### The Wax Moth

The wax moth (*Galleria mellonella* L.) is known under several names in different parts of the United States.[57] It is known by beekeepers under the names "greater wax moth," "wax moth," "bee moth," "bee miller," and "wax miller." It probably is best known in its larval or worm stage as the "wax worm" or "web worm."

This insect is widely distributed throughout the temperate zone, but does the most damage in southern states where the winters are mild. The high altitudes and long cold winters of some of the mountain states seem

[57]Whitcomb, Warren, Jr. 1936. The wax moth and its control. *U.S.D.A. Circ.* 386.

to prevent the insect from becoming established under such conditions. Losses in southern states are considerably higher than in the North because of the longer season of bee and moth activity. Weak colonies easily become infested while colonies strong in bees tend to keep the infestation out or at a minimum. Apiary practices in the South, especially that of keeping two or more hive bodies of empty combs on the colonies during a long, slow honeyflow, or late in the fall for storage, increase the opportunity for wax moth damage. Combs in supers may be ruined even when the colony is of fair strength.

In many cases of starvation, the wax-moth larvae may destroy the combs, particularly in the South, before the beekeeper becomes aware of the death of the colony. Since bees in box hives cannot be examined, requeened, or otherwise controlled, such colonies are likely to become weak. Under these conditions an invasion of the wax moth destroys the colony and the combs. Probably the most noticeable loss from wax-moth injury is in combs in storage, especially if these combs are in a warm protected place. Often before the beekeeper realizes, the destruction of the combs by the larvae or worms is so complete as to leave the destroyed combs only as a mass of webs and debris. In the North such losses are more common than the destruction of entire colonies.

The destruction by wax-moth larvae of combs in bee trees is probably an aid in preventing the spread of bee disease through the robbing of honey by other bees. In those areas where queen breeders and package shippers are located, the destruction of such stray colonies has been of real value. Since the germs of American foulbrood have been found in the excrement of wax-moth larvae, there is a theoretical possibility that the disease might be spread by this means, but actually there is no evidence to warrant this assumption. It has been shown that infectious material in a colony dying of this disease remains even after the combs have been destroyed by wax moths.

## Life History

The egg of the wax moth is small, white, somewhat elliptical, and rather inconspicuous. The size and shape vary somewhat, depending on the number of eggs laid in one spot and the character of the site in which they are laid. Where hives and combs are occupied by bees, the eggs of the wax moth are probably laid most frequently in the cracks between hive parts; that is, between supers, between hive body and bottom board, or between the top super and cover. With weak colonies or with combs without bees, eggs are laid inside the hive in more or less protected places. Egg masses in the hive are difficult to see and often may be overlooked.

At 75° to 80° F. the eggs hatch in from 5 to 8 days, but with low temperatures (50° to 60°) the period may extend to 35 days. Under apiary conditions the incubation period is probably almost entirely dependent on temperature.

The young larvae, upon hatching, are very active and do not look like the familiar wax worms. Beekeepers have called them wood lice and have not connected the appearance of these forms with the damage from the worms which they noticed later. They are often seen upon the inner covers of hives and in the cracks between supers and hive parts. The young larvae attempt to burrow into the wax almost immediately after emergence from the egg. The first burrows are often incomplete and may be mere roughenings of the surface of the wax. After the first day, however, they make small tunnels between the cells and toward the midrib of the comb (Fig. 303) in which the typical silken strands of the web may be found. The growth of the larvae depends upon several factors, of which the quantity and quality of food and the temperature are most important.

The length of the larval period, from the time of the hatching of the egg until pupation, has been found to range from 28 days to 4 months and even as long as 140 days, or nearly 5 months. During this period the large larvae have grown from about one twenty-fifth of an inch to seven-eighths of an inch in length. The food of the larvae is not confined to beeswax. It is even probable that little pure wax is digested but rather that the larvae derive most of their nourishment from the impurities in the wax of the combs.

The larvae prefer the darker brood combs to the white extracting combs. In the empty brood combs the larvae confine their work mostly to the midrib and bases of the cells. Combs often are found with perhaps the outer one fourth of the length of the cells untouched and the cen-

FIGURE 303. Webs and tunnels made by larvae of the wax moth in a comb.

FIGURE 304. The cocoons of the wax moth along the bottom bar of a frame and between the bottom of the comb and the bottom bar.

tral portion, including the midrib, completely destroyed and replaced with a mass of webs and refuse.

Before pupation the full-grown larva spins a dense silken cocoon. Usually this cocoon is firmly attached to the side of the hive, to the frame (Fig. 304), or other solid support, but in some cases the cocoon is found in the mass of tunnels and refuse of the wax of the combs or on the bottom of the hive. In many cases a shallow hollow is chewed out of the wood of the hive or frame and the cocoon is placed in this for added protection. The fully grown larvae migrate considerable distances before the cocoons are spun, and pupal cases may be found beneath the hive and even on the more protected parts of the hive stand. Within the cocoon the larva changes to the pupa. The duration of the pupal stage within the cocoon ranges from 8 to 62 days, depending on temperature. As with many other insects, the pupal period allows the wax worm to pass through the fall and winter protected against climatic influence to a large extent. In the South, especially during warm winters, the adults may emerge at any time during the winter.

The adult wax moths are about three fourths of an inch in length and have a wing spread of about 1 to 1¼ inches in well-developed specimens. They are commonly seen in the resting position with their grayish-brown wings folded rooflike closely about them. The moths are not easily disturbed but when molested they run rapidly before they take wing.

The males are slightly smaller than the females and may be distinguished from them by the shape of the outer margin of the fore wing,

which is smooth in the female but roundly notched or scalloped in the male. The protruding palps of the female are another easily distinguishable character. The female begins to deposit eggs 4 to 10 days after emergence and continues as long as her egg-laying vitality lasts. Egg laying may be rapid at times. As many as 102 eggs have been deposited by a female in 1 minute. According to Whicomb,[57] the total number of eggs laid by a female varies considerably, but it usually is less than 300. The adults may live as long as 3 weeks.

### Other Moths Causing Damage to Stored Combs*

Mention has been made of the lesser wax moth (*Achroia grisella,* Fabr.), but this moth does not cause so much damage to stored combs as does the wax moth. The work of the lesser wax moth differs from that of the wax moth in that the tunnels are smaller, the webs finer, and feeding and webbing are more confined to the outer surface of the combs. The Mediterranean flour moth (*Ephestia kuehniella,* Zell.) is a pollen feeder rather than a wax feeder but does some damage to combs by boring tunnels into brood cells and consuming the food intended for the developing bee larvae. All of these moths may be controlled by the methods given for the wax moth.

### Control

The bees are the greatest and most effective natural enemies of the wax moth. They will, when the colony is strong, carry them bodily out of the hive. There is no better insurance against the ravages of the pest than to have the combs populated with a strong colony headed by a vigorous queen. Climatic conditions, particularly temperature, are effective in limiting the spread of the wax moth and the rate of growth, and thereby the amount of damage done by the insect. Strong colonies are aided by cleanliness of hives, removal of propolis, burr combs, and refuse on the bottom board which provide protection for larvae of the wax moth. Beekeeping practices and manipulations should be based on the assumption that the wax moth in some stage may be present in the hives at all times.

For controlling the wax moth on combs in storage, two methods of attack are possible. Some substance may be used which will kill the wax moth or some method adopted of repelling the adults so that eggs are not deposited on or near the stored combs. Of the killing substances, fumigants (poisonous gases) have proved most satisfactory, but, with the exception of paradichlorobenzene, the gases do not remain in the supers long enough to have any distinct repellent action. Fumigants for wax

*Editor's Note—Other moths causing damage to honeycombs include the Indian meal moth (*Plodia interpunctella,* Hbn.), the almond moth (*Ephestia cautella,* Walk.), and three moths apparently not having common names: *Vitula edmandsii,* Pack., *Aphomia sociella,* L., and *Vitula serratilinella,* Rag. *See*: Milum, V. G. 1940. Moth pests of honeybee combs. *Gleanings in Bee Culture* 68(8):488-493.

moth control are substances, whether liquid or solid, that form a killing gas which diffuses through the stored equipment and is inhaled by the insect.

Except in the Northern States where protecting stored combs is not a great problem, combs must be fumigated from time to time to prevent damage by larvae of the wax moth and other moths causing similar damage. For this purpose storage space, both mouseproof and bee tight, for the proper fumigation of combs should be available.

If the supers of empty combs are to be fumigated elsewhere than in an airtight room, they should be stacked tightly together and covered to prevent the entrance of moths at all times. Whitcomb[57] recommends that the cracks between the supers be covered with gummed tape. When gases heavier than air are used, such as that given off by paradichlorobenzene, it is important that the bottom of the stacks be closed tightly, and the reverse is true of the top covers of the stacks when gases are lighter than air.

In order that stored empty supers could be fumigated, rooms have been constructed in honey houses, and some beekeepers have even installed means of ventilating these rooms before entering them when dangerous fumigants were used. It is however, difficult, expensive, and practically impossible to construct an airtight room. When dangerous fumigants are used, they are liable to seep from the storage room into other parts of the honey house. The deaths of a number of people from cyanide poisoning have been reported when this fumigant has been used inside honey houses without proper precautions, and fires have been started when carbon disulfide has been used. Therefore, when such dangerous materials are used, stored combs should be fumigated in a separate building or outdoors.

In California it is unlawful to stack supers of combs outdoors, because of the danger of the spread of disease by robbing. Where it is not against the law, a platform on which supers can be stacked outside the honey house provides for their fumigation with safety. This leaves available much more space in the honey house, and reduces the danger from cyanide poisoning as well as from fire. Cale[58] has described a wooden platform or floor, which can be constructed for outdoor storage, on which supers of empty combs can be tightly stacked on 2-inch boards for drying, covering, and later fumigation.

Paradichlorobenzene ("PDB") is a white crystalline substance which changes slowly into a gas. The gas is not unpleasant to smell, is noninjurious to people at the concentration obtained when used as directed, and is heavier than air. It is noninflammable and nonexplosive. It kills adults and larvae of the wax moth but is not effective against the eggs. In fumigating with paradichlorobenzene the supers should be stacked as

---

[58]Cale, G. H. 1943. Inexpensive super storage. *Amer. Bee Jour.* 83(11):422-423.

tightly as possible and the cracks between covered with gummed paper strips. Two or three tablespoons of the crystals should be placed on the top of the frames of the top super and the cover put tightly in place. The crystals may be sprinkled directly on the top bars of the frames or put on a piece of paper laid on the top bars. Since the gas is nonpoisonous and not disagreeable, treatment may be made in ordinary storage without taking the infested material out of doors. At intervals during the storage season the covers of the stack should be raised, and unless some crystals are still present, more should be added. Paradichlorobenzene is more effective at temperatures above 70° F. and volatilizes more rapidly as the temperature rises. Inspections of stored materials should be made at intervals of 2 or 3 weeks, depending on the temperature of the storehouse and the prevalence of adult moths.

Carbon disulphide has been a standard fumigant for wax moths and similar insects until recently, and with proper precautions is still satisfactory. As commonly sold commercially, it is a more or less yellowish, somewhat oily liquid that changes readily at ordinary temperatures into an ill-smelling gas. The liquid is about one-fourth heavier than water, and the gas is heavier than the air.

*It is highly inflammable. The vapor is explosive when mixed with air in certain proportions. Therefore, this chemical must not be handled around fire of any kind.*

Preferably it should be used out of doors or in a well-ventilated or open shed. In using carbon disulphide the supers should be sealed in the same manner as for paradichlorobenzene. Carbon disulphide is effective against larvae and adults but not against eggs; consequently, it may be necessary to repeat the treatment after any eggs have had time to hatch.

Calcium cyanide is effective against the larvae, pupae, and adults of the wax moth, but cannot be depended on to destroy the eggs. It is obtainable both as a dust and as granular crystals. For fumigating bee equipment the granular form is preferable. Moisture, which generally is present in the air, causes the crystals to decompose slowly giving off cyanide gas. *The gas is extremely poisonous to people and animals. It must not be breathed. A gas mask should be worn whenever the beekeeper enters a building where cyanide has been used for fumigation and other persons should not be permitted to enter. If a gas mask is not available any room or building in which cyanide fumigant has been used should be thoroughly aired before it is entered.* For further details concerning the use of calcium cyanide see "Treatment and Control" under the section on American foulbrood.

The fumes from burning sulfur control the larvae and adults of the wax moths but are ineffective against eggs. Here again there is danger from fire.

More recently two new fumigants have been used that have been found to be much more efficient than any of those mentioned earlier

herein. Krebs,[59] State Apiarist of California, in 1939, recommended the use of two new insecticide chemicals, an ethylene dichloride-carbon tetrachloride mixture, known as chlorosol, and methyl bromide, both of which apparently kill all stages of moths including the eggs.

Chlorosol, a liquid which boils at 170° to 175° F., evaporates slowly, and is nonflammable; therefore, it can be used with little danger. Since the gas from this product is heavier than air, the liquid should be placed in open pans on top of the piles of supers. One gallon of liquid should be used for each 1000 cubic feet of space to be fumigated. This insecticide can be purchased or it can be prepared by mixing 3 parts of ethylene dichloride with 1 part of carbon tetrachloride (the chemical used in some fire extinguishers).

Methyl bromide, probably one of the most efficient insecticides in use at the present time, is a colorless, almost odorless liquid which comes under pressure in 1-pound cans and 10-pound cylinders. It boils at 40° F. and vaporizes immediately on release from the container. It is very easy to apply and is much quicker in its action than other fumigants. Since methyl bromide is highly poisonous, beekeepers using this insecticide should take every precaution and vacate the room at once. Its poisonous action on human beings, however, is not to be compared with the quick action of cyanide. If the 1-pound container is used, the can should be opened and the contents quickly thrown in every direction in the room with a swishing motion away from the person handling the container. If a cylinder is used, the valve is opened and the vapor is sprayed in all directions from the nozzle. The vapor is heavier than air and thus should be sprayed upward when released. One pound of methyl bromide is sufficient for 1000 cubic feet of space. It is nonflammable and leaves no residue. It will penetrate every crevice no matter how small and will kill all stages of insect life. It also will quickly exterminate rats, mice, and other vermin. After the fumigation is completed all buildings should be thoroughly aired before they are entered.

## The Bee Louse

The common name "bee louse" for *Braula coeca* Nitzsch is not an appropriate one since this wingless insect is not a louse. Since the name is well established in many languages there seems to be no necessity for the use of another common name for the species. It is found commonly in parts of southern Europe. From time to time it has been imported into the United States[60] probably attached to the bodies of queen bees, but it has never become established and has never been observed, except in

---

[59]Krebs, H. M. 1939. Get that wax moth—egg and all. *Gleanings in Bee Culture* 67(7):431-432.

[60]Phillips, E. F. 1925. The bee-louse, *Braula coeca*, in the United States. *U.S.D.A. Circ.* 334. 12 pp.

FIGURE 305. Colonies in the South, kept on platforms as a protection against ants and termites. (*Photo courtesy E. C. Bessonet*)

rather restricted localities in Maryland and Pennsylvania. These insects may occasionally be found on worker bees and drones, but they mainly infest queen bees. As a rule the adult louse does little damage, although it may eventually cause the death of the queen. It is not a true parasite, but feeds on the nectar or honey which it extracts from the mouth parts of its host. The greatest damage is from the burrowings of the larvae in the cappings of honeycombs, which can be seen underneath the surface of sealed combs of honey.

Various remedies have been recommended, such as opening an infested colony in the evening and sprinkling the bees thoroughly with honey water. In cleaning up the diluted honey the bees are said to remove the *Braula coeca* larvae. It is also claimed that smoking the colony vigorously with tobacco smoke causes the lice to die and drop to the bottom board. These recommendations, however, have not been substantiated.

## Ants and Termites

Various species of ants are common throughout most sections of the United States. Some are destructive while others are only a nuisance. In some sections of the South the Argentine ant is very troublesome and destructive, attacking the brood, bees, and honey. The beehives must be kept off the ground (Fig. 305) and for further protection should be placed on stands with legs which rest in cans of oil. The ant nests can be destroyed by punching holes in the earth around them to a depth of 8 to 12 inches, pouring 1 tablespoon of carbon disulfide into each hole, and covering the tops of the holes with moist earth. Cyanide also is effective. Poison baits may be used to control some kinds of ants, but since they

also are deadly to bees they should be placed in tin containers having openings too small for bees to enter.

Several other species of common ants are pests in bee yards and around honey houses. They may be found under bottom boards of hives or between the inner and outer covers. They generally are attracted by the sweet honey or dead bees. They do little or no damage being merely a nuisance to the beekeeper, and can be controlled by the usual methods. Among some of these species are the tiny red Pharaoh ant and the little black ant found in the cooler parts of the temperate zone. These small ants generally breed indoors, beneath floors, in wall spaces or in partially decayed wood of old buildings. Another species commonly found in fields, pastures, and yards, under conditions similar to those in such states as Oklahoma, is the red harvester ant.

The nests of some ants remain in the same locality for many years; others are more temporary. Their size and depth in the soil vary greatly, according to the species. Some are shallow, scarcely penetrating the ground; others may be 1 or 2 feet and some even 6 or 8 feet deep. Cleanliness is important in ant control. Honey should be kept in closed containers, and shelves, tables, and floors should be clean. Refuse around the honey house should be kept in tight containers and removed or destroyed as quickly as possible, together with dead bees and other refuse in the apiary.

Termites, subterranean insects commonly called white ants, occur throughout the United States and do serious damage in all parts except the extreme North. They burrow into the wood of bottom boards and other hive parts in contact with the ground. Their control usually consists in insulation, either mechanical or chemical. Wherever termites are prevalent, bottom boards should be raised off the ground on cement stands. Chemical insulation would involve putting a chemical barrier in the soil or impregnating the bottom boards with a standard wood preservative.

One of the new chlorinated hydrocarbons, known as chlordane, has recently been found very effective against ants. Chlordane concentrate is a viscous liquid considerably heavier than water, insoluble in water but soluble in several organic solvents. A cup (200 cc.) of a 2.5 to 3 per cent solution of technical chlordane poured into the openings of a ground colony, or sprayed into wall or floor cavities from which ants emerge, has been found to destroy a nest within 24 hours, with no reestablishment of colonies in new places. Larger or smaller amounts may be required, dependent upon the size of the colony. A dust impregnated with 2 per cent chlordane can be used on benches, under floors, walks, walls, and especially in cracks and crevices where ants may go. Ants are not repelled from treated tunnels or nesting places, but cross chlordane-treated areas freely. Carbon tetrachloride and 95 per cent alcohol are satisfactory solvents for the technical concentrate. Other diluents, such

as petroleum oils or water, will serve as well. The toxic effect of chlordane on warm-blooded animals is not known, but care should be taken in its use where bees might come in contact with it. No harmful effects on persons using chlordane have been noticed other than a slight irritation of the nose and eyes caused by fumes from the concentrated chemical.

## Minor Enemies of Bees

There have been numerous reports of birds catching and killing bees. However, the king bird, commonly called the bee martin, is the most accused bird in this country. Since the number of bees caught and killed by the king bird is not great, it is likely that serious damage only occurs where queens are being reared.

The foremost animal killer of bees is the skunk. While he likes honey, he is seldom able to reach it and contents himself with feeding on bees at the entrance of the hive in the evening and during the night. Pellett[61] states that the skunk is able to satisfy his appetite without getting stung, seeming to roll the bee under his foot to kill it and devouring the body at his leisure.

The toad, while consuming many destructive insects, is not averse to eating honey bees. He apparently is able to catch bees with his tongue and to eat them without being stung. In California certain small lizards prey on bees. Except in unusual cases they seldom do appreciable damage.

Particularly in the South near marshy places, dragonflies occur in sufficiently large numbers to cause serious losses by catching honey bees in flight and devouring them. There are places in Florida where queen-rearing operations have suffered substantial losses on their account. The robber fly also becomes a serious menace to beekeeping and queen-rearing activities in certain parts of the South where they are numerous. Other insects which are reported to do minor damage to honey bees include the praying mantis, certain spiders, blister beetles, wasps, and hornets.

Rats, mice, and other small mammals are destructive to combs, particularly during winter, providing they are able to gain entrance to the hive or to stored combs. Mice probably do the most damage, invading the hive in winter and destroying combs in order to provide a space in which to build their nests. They also feed on dead bees, honey, and other food which they can reach. In an effort to obtain honey for food, bears do great damage to bees, combs, and equipment. For additional information concerning bears see Chapter VIII entitled "The Apiary."

---

[61]Pellett, Frank C. 1931. *The Romance of the Hive.* New York, N.Y. The Abingdon Press. p. 107.

# INDEX